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Technical Report 198

The Nihoku Ecosystem Restoration Project: A case study in predator exclusion fencing, ecosystem restoration, and seabird translocation

September 2018

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PCSU is a cooperative program between the University of Hawai`i and U.S. National Park Service, Cooperative Ecological Studies Unit.

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Recommended Citation:
Young, L.C., J.H. Behnke, E.A. Vanderwerf, A.F. Raine, C. Mitchell, C.R. Kohley, M. Dalton, M. Mitchell, H. Tonneson, M. DeMotta, G. Wallace, H. Nevins, C.S. Hall and K. Uyehara. 2018. The Nihoku Ecosystem Restoration Project: A case study in predator exclusion fencing, ecosystem restoration, and seabird translocation. Pacific Cooperative Studies Unit Technical Report 198. University of Hawaiʻi at Mānoa, Department of Botany. Honolulu, HI. 83 pages.

Key words: Newell's Shearwater (*Puffinus auricularis newelli*), Hawaiian Petrel (*Pterodroma sandwichensis*), Nēnē (*Branta sandvicensis*), The Nihoku Ecosystem Restoration Project

Place key words: Kīlauea Point National Wildlife Refuge, Hawaiʻi

About this technical report series:

This technical report series began in 1973 with the formation of the Cooperative National Park Resources Studies Unit at the University of Hawai'i at Mānoa. In 2000, it continued under the Pacific Cooperative Studies Unit (PCSU). The series currently is supported by the PCSU.

The Pacific Cooperative Studies Unit at the University of Hawai'i at Mānoa works to protect cultural and natural biodiversity in the Pacific while encouraging a sustainable economy. PCSU works cooperatively with private, state and federal land management organizations, allowing them to pool and coordinate their efforts to address problems across the landscape.

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EXECUTIVE SUMMARY

Newell’s Shearwater (*Puffinus auricularis newelli;* NESH) and Hawaiian Petrel (*Pterodroma sandwichensis;* HAPE) are both listed under the Endangered Species Act of 1973 and are declining due to collisions with power lines and structures, light attraction, predation by feral cats, pigs, rats, and introduced Barn Owls, habitat degradation by feral ungulates (pigs, goats) and invasive exotic plants. Protection of NESH and HAPE on their nesting grounds and reduction of collision and lighting hazards are high priority recovery actions for these species. Given the challenges in protecting nesting birds in their rugged montane habitats, it has long been desirable to also create breeding colonies of both species in more accessible locations that offer a higher level of protection. Translocation of birds to breeding sites within predator exclusion fences was ranked as priority 1 in the interagency 5-year Action Plan for Newell’s Shearwater and Hawaiian Petrel. In 2012, funding became available through several programs to undertake this action at Kīlauea Point National Wildlife Refuge (KPNWR), which is home to one of the largest seabird colonies in the main Hawaiian Islands. The project was named the “Nihoku Ecosystem Restoration Project” after the area on the Refuge where the placement of the future colony was planned. The Nihoku Ecosystem Restoration Project is a result of a large partnership between multiple government agencies and non-profit groups who have come together to help preserve the native species of Hawaiʻi. There were four stages to this multi-faceted project: permitting and biological monitoring, fence construction, restoration and predator eradication, followed by translocation of the birds to the newly secured habitat. The translocation component is expected to last five years and involve up to 90 individuals each of NESH and HAPE.

Prior to fence construction, baseline monitoring data were collected in order to provide a record of initial site conditions and species diversity. Surveys were conducted quarterly from 2012-2014, investigating diversity and richness of plant, invertebrate, mammalian, and avian species. A 650 m (2130 ft) long predator proof fence was completed at Nihoku in September 2014, enclosing 2.5 ha (6.2 ac), and all mammalian predators were eradicated by March 2015. From 2015-2017, approximately 40% of the fenced area (~1 ha) was cleared of non-native vegetation using heavy machinery and herbicide application. A water catchment and irrigation system was installed, and over 18,000 native plants representing 37 native species were out-planted in the restoration area. The plant species selected are low-in-stature, making burrow excavation easier for seabirds while simultaneously providing forage for Nēnē (*Branta sandvicensis*). Habitat restoration was done in phases (10-15% of the project per year) and will be continued until the majority of the area has been restored. In addition to habitat restoration, 50 artificial burrows were installed in the restoration to facilitate translocation activities.

From 2012-2017 potential source colonies of NESH and HAPE were located by the Kauaʻi Endangered Seabird Recovery Project (KESRP) with visual, auditory, and ground searching methods at locations around Kauaʻi. The sites that were selected as source colonies for both species were Upper Limahuli Preserve (owned by the National Tropical Botanical Garden; NTBG) and several sites within the Hono o Nā Pali Natural Area Reserve system. These sites had high call rates, high burrow densities to provide an adequate source of chicks for the

translocation, and had active predator control operations in place to offset any potential impacts of the monitoring. Translocation protocols were developed based on previous methods developed in New Zealand; on the ground training was done by the translocation team by visiting active projects in New Zealand. In year one, 10 HAPE and eight NESH were translocated, and the goal is to translocate up to 20 in subsequent years for a cohort size of 90 birds of each species over a five year period. Post-translocation monitoring has been initiated to gauge the level of success, and social attraction has been implemented in an attempt to attract adults to the area. It is anticipated that the chicks raised during this project will return to breed at Nihoku when they are 65-6 years old; for the first cohort released in 2015 this would be starting in 2020. Once this occurs, Nihoku will be the first predator-free breeding area of both species in Hawaiʻi.

1 INTRODUCTION

1.1 Project background

Islands make up 1.3% of the U.S. land area yet are home to 43% of species listed under the Endangered Species Act (ESA) and 53% of extinctions (Reaser et al. 2007, Spatz et al. 2017). Invasive species are one of the primary threats to island ecosystems and are responsible for approximately two-thirds of all island extinctions in the past 400 years (Blackburn et al. 2004, Reaser et al. 2007, Helmstedt et al. 2014, Tershy et al. 2015). Hawaiʻi not only is the state with the greatest number of threatened, endangered, and extinct species, but also the state with the highest proportion of endemic flora and fauna (Ziegler 2002). Non-native mammals, primarily rats (*Rattus* spp.), cats (*Felis catus*), mongooses (*Herpestes auropunctatus*), goats (*Capra hircus*), sheep (*Ovis aries*), and pigs (*Sus scrofa*), in addition to invasive weeds, disease, and fire, have had devastating impacts on ESA listed and at-risk species and are major factors in population declines and extinctions in Hawaiʻi and elsewhere (Ziegler 2002, Reaser et al. 2007).

Newell's Shearwater (NESH; *Puffinus auricularis newelli*) and Hawaiian Petrel (HAPE; *Pterodroma sandwichensis*) are listed under the ESA and are Hawaiʻi's only endemic seabirds. They are both declining due collisions with power lines, light attraction, predation by feral domestic cats, rats, mongooses, and introduced Barn Owls (*Tyto alba;* BAOW), and habitat degradation by feral ungulates (pigs, goats) and invasive exotic plants. Radar survey data indicate the populations of NESH and HAPE on Kauaʻi have declined by 94% and 78%, respectively, between 1993-2013 (Raine et al. 2017). Protection of NESH and HAPE on their nesting grounds and reduction of collision and lighting hazards are high priority recovery actions for these species. One of the most effective ways to secure their nesting grounds is to exclude predators from entering the area with fencing and subsequent mammalian predator removal. However, since virtually all of their current breeding colonies are in high-elevation montane environments, effective predator exclusion fencing has not been possible until very recently.

Predator exclusion fencing, i.e., fencing designed to keep all non-volant terrestrial vertebrates out of an area, has been used widely with positive results (Day & MacGibbon 2002, Young et al. 2013, VanderWerf et al. 2014, Tanentzap & Lloyd 2017, Anson 2017). The fencing excludes animals as small as two-day old mice, and prevents animals from digging under or climbing over the fence. Fence designs developed in New Zealand have been shown previously to exclude all rodents and other mammalian pests in New Zealand, and more recently in Hawaiʻi (Day & MacGibbon 2002; Young et al. 2012 and 2013). Resource managers in New Zealand have built more than 52 predator exclusion fences that protect more than 10,000 hectares, and these fenced areas are now refuges for a majority of the endangered species. Six predator exclusion fences have been built in Hawaiʻi to date that exclude all mammalian predators. The use of predator fencing greatly increases the effectiveness of existing animal control efforts, shifting the focus from perpetually attempting to control predator numbers to eradication (Long and Robley 2004). Predator fencing makes it feasible to remove all animals from within the fenced unit and to focus control efforts on buffer areas around the perimeter of the fence. In Hawaiʻi, the use of predator fencing is especially promising because it can provide areas within which the entire ecosystem, including native vegetation, can recover and where birds and snails can breed and forage free from the threats of introduced terrestrial vertebrate predators (MacGibbon and Calvert 2002; VanderWerf et al. 2014).

The impetus for this project was a settlement from a lawsuit against various entities for take of NESH and HAPE under the ESA on the island of Kauaʻi, Hawaiʻi. This project was conceived in 2011 and began in earnest in 2012 in order to create breeding colonies of NESH and HAPE that were safe from predators as well as from power lines and light attraction. This would be accomplished through constructing a predator exclusion fence, removing the predators, and establishing the seabird colonies through translocation and social attraction. The site chosen for this project was Kīlauea Point National Wildlife Refuge (KPNWR) on the North coast of Kauaʻi, Hawaiʻi. The Refuge was chosen for its location as well as its permanent, dedicated land use for conservation purposes.

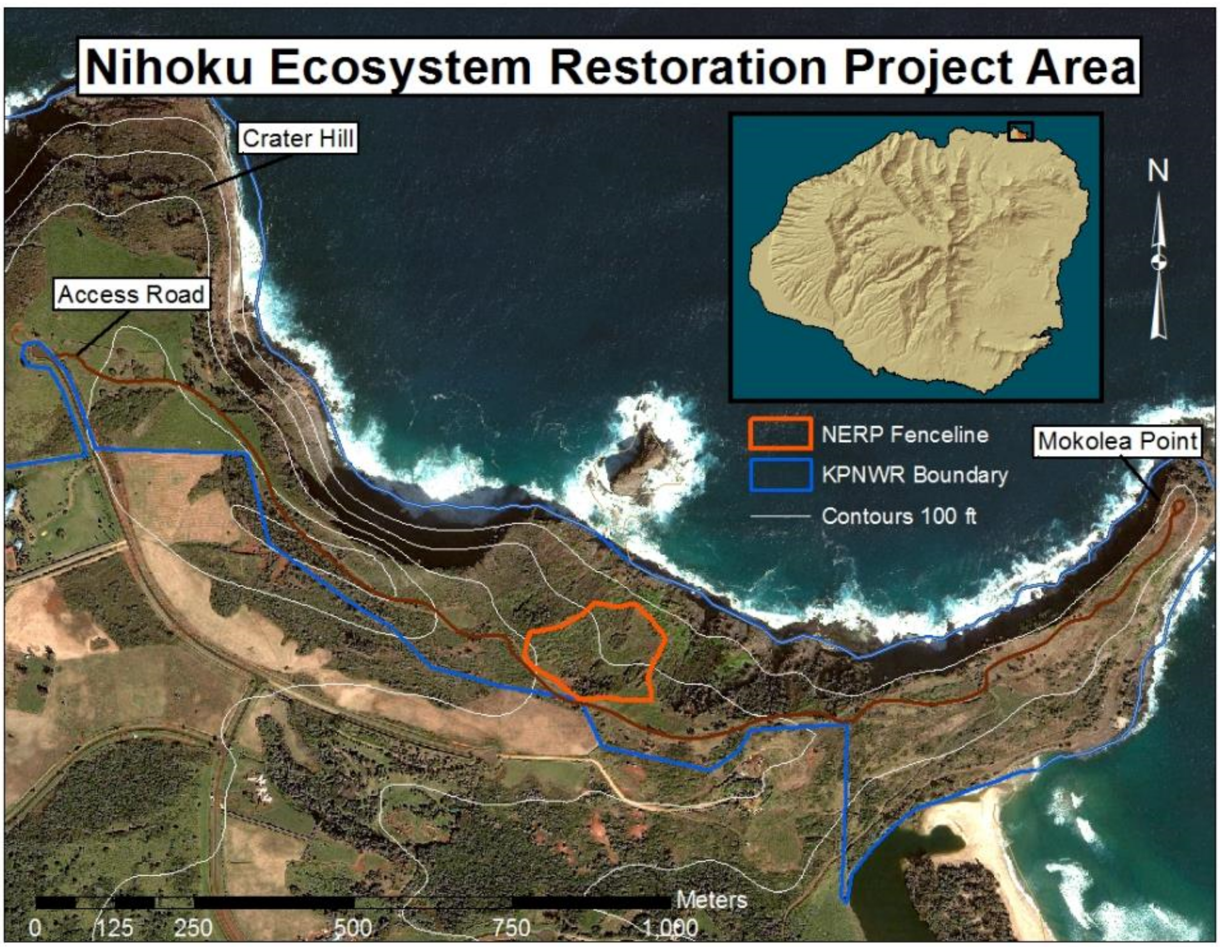

Figure 1: Nihoku Ecosystem Restoration Project area within Kilauea Point National Wildlife Refuge (KPNWR).

KPNWR is managed by the U.S. Fish and Wildlife Service (USFWS) under the U.S. Department of the Interior, and is one of the few places in the main Hawaiian Islands (MHI) with an abundant diversity of seabirds (Pyle and Pyle 2017). A remarkable 27 seabird species have been observed at Kīlauea Point over the years, making it one of the premier sites for seabirds in Hawaiʻi (USFWS 2017). Wedge-tailed Shearwaters (*Ardenna pacifica*) are the most numerous seabird species on the Refuge, with an estimated 8,000-15,000 breeding pairs. The Red-footed Booby (*Sula sula*) colony is the largest in the MHI, with a maximum of 2,536 nests counted. About 200 pairs of Laysan Albatrosses (*Phoebastria immutabilis*) nest on and near KPNWR, the largest colony outside the Northwestern Hawaiian Islands (NWHI). About 350 pairs of Red-tailed Tropicbirds (*Phaethon rubricauda*) nest on the Refuge, as well as smaller numbers of White-tailed Tropicbirds (*P. lepturus*). The Refuge harbors up to 13 breeding pairs of NESH. The Refuge is the only easily accessible location where this threatened species nests and thus is a source of much information on NESH breeding biology. Additionally, there are 300 Nēnē (Hawaiian Goose, *Branta sanvicensis;* HAGO) in the Kīlauea Point area, making the Refuge population one of the largest concentrations on the island as well as providing a high-island refugium for seabird populations potentially displaced by sea level rise as a result of climate change in the Northwestern Hawaiian Islands (NWHI; Reynolds et al. 2017).

The area on the Refuge that was chosen to construct the fence, called Nihoku, is between the Crater Hill and Mōkōlea Point sections of the Refuge. It was chosen for its bowl-shaped sloped topography that faces northeast into the prevailing winds. The site has no visible light sources, has ideal wind and slope conditions to facilitate flight for the birds, and was suitable for a fully enclosed predator exclusion fence (vs. a peninsula style fence). However, the habitat in the chosen location was not suitable for either NESH or HAPE and a high level of habitat restoration would need to occur to make it suitable for both species. Thus in order to create a safe and suitable breeding colony for these two species, considerable modification and effort was needed. The project was named the "Nihoku Ecosystem Restoration Project" (NERP) in recognition that the ultimate goal, in addition to creating a seabird colony, was a full ecosystem restoration. There were four stages to this multi-faceted project: permitting and biological monitoring, fence construction, restoration and predator eradication, followed by translocation of the birds to the newly secured habitat.

The purpose of this report is to provide an overview of the process that was undertaken to complete this project, including the fence construction, planning for seabird translocations, and the legal compliance. Predator exclusion fencing and seabird translocation projects continue to be initiated in Hawaiʻi and it is hoped that the information compiled from this experience will contribute toward the greater body of knowledge on the subject, and serve to facilitate planning of future projects.

1.2 Objectives

The objective of this project was to create safe nesting habitat for Newell's Shearwaters and Hawaiian Petrels, Hawaiʻi's only two endemic seabirds, and to enhance the existing breeding colonies of Laysan Albatross and Nēnē that already nest in the area.

Evaluation Metrics:

The following metrics were used to evaluate success at each stage of the project:

- Area of habitat enclosed with predator exclusion fencing and cleared of predators

- Number of seabird breeding pairs protected, by species
- Change in number of seabird breeding pairs, by species
- Change in breeding success of listed bird species (HAPE, NESH and Nēnē)
- Numbers of NESH and HAPE chicks successfully translocated
- Number of NESH and HAPE chicks successfully fledged per year, including natural nests and translocated chicks.
- Numbers of NESH and HAPE breeding pairs resulting from natural colonization (socially attracted)
- Numbers of NESH and HAPE breeding pairs resulting from translocated chicks.

1.3 Partners

The Nihoku Ecosystem Restoration Project is a result of a large partnership between multiple government agencies and non-profit groups who have come together to help preserve the native species of Hawaiʻi. The USFWS serves as the landowner and partner where the project is conducted. The USFWS works with others to conserve, protect, and enhance fish, wildlife, plants, and their habitats for the continuing benefit of the American people, and is steward to the National Wildlife Refuge System. Kīlauea Point National Wildlife Refuge is home to Nihoku, and was established in 1985 to preserve and enhance seabird nesting colonies.

Pacific Rim Conservation (PRC) is a non-profit organization that coordinates the Nihoku Ecosystem Restoration Project with all partners. Their role is to oversee all aspects of the restoration, predator exclusion fence, and care of the translocated chicks. PRC conserves and restores native species throughout Hawaiʻi and the Pacific.

The Kauaʻi Endangered Seabird Recovery Project is a joint project of the Pacific Cooperative Studies Unit of the Research Corporation of the University of Hawaiʻi and the Hawaiʻi Division of Forestry and Wildlife (DOFAW) project. Their role is to undertake all of the montane habitat management and research of the seabirds being brought to Nihoku, particularly locating suitable chicks for translocation, monitoring them through the season and physically translocating them to Nihoku. The project focuses primarily on conservation and research of Kauaʻi's three endangered seabirds– Newell's Shearwater, Hawaiian Petrel and Band-rumped Storm-Petrel (*Oceanodroma castro*).

American Bird Conservancy (ABC) is a funder and assists with project development and execution when needed. ABC's focus is on efficiency and working in partnership, to take on the toughest problems facing birds today, innovating and building on sound science to halt extinctions, protect habitats, eliminate threats, and build capacity for bird conservation.

The National Fish and Wildlife Foundation (NFWF) provides funding support for Nihoku. Chartered by Congress in 1984, NFWF works to protect and restore the nation's fish, wildlife, plants and habitats. Working with federal, corporate and individual partners, NFWF has funded more than 4,000 organizations and committed more than $2.9 billion to conservation projects.

The National Tropical Botanical Garden (NTBG) is a Hawaiʻi-based not-for-profit institution dedicated to tropical plant research, conservation, and education. NTBG assists with habitat restoration at Nihoku, and its Upper Limahuli Preserve serves as a source colony from which some of the translocated seabirds were taken.

The David and Lucille Packard Foundation Marine Birds Program focuses on enhancing ocean biodiversity by protecting seabirds and shorebirds and their habitats around the world. The Foundation provides funding support for this project.

1.4 Timeline and chronology

- 2011 – Project initiation and Nihoku selected as project site
- 9/2012 – Permitting process initiated for all county, state, and federal permits
- 2012-2014 – Pre-construction biological monitoring (conducted quarterly)
- 2012-2017 – Source colony searches undertaken to locate seabirds for translocation
- 4/2013 – Archaeological assessment performed
- 5/2013 – Scoping letters sent to community & stakeholders for the environmental assessment of fence construction
- 3/2014 – Final Environmental Assessment of the Nihoku Ecosystem Restoration Project at Kīlauea Point National Wildlife Refuge and Finding of No Significant Impact statement
- 5/2014 – Special Management Area (SMA) permit issued by the county of Kauaʻi
- 6/2014 – Ground-breaking blessing ceremony. Fence construction started
- 9/2014 – Fence construction completed
- 11/2014 – Mammalian predator eradication initiated
- 3/2015 – Mammalian predator eradication completed (including mice)
- 3/2015 – Phase I habitat restoration started (~0.2 ha). Construction of water catchment system. Installation of seabird nest boxes, social attraction system
- 10/2015 – Environmental Assessment of "Management Actions for immediate implementation to reduce the potential for extirpation of ʻUaʻu (Hawaiian Petrel) from Kauaʻi" and Finding of No Significant Impact statement
- 10/2015 – First HAPE translocation commences
- 12/2015 – First HAPE cohort fledged from Nihoku (9 of 10 chicks)
- 5/2016 – Phase II habitat restoration (~0.4 ha) with volunteer-coordinated effort
- 8/2016 – Final Environmental Assessment of "ʻAʻo (Newell's Shearwater) Management Actions" and Finding of No Significant Impact statement
- 9/2016 – First NESH translocation
- 10/2016 – First NESH cohort fledged from Nihoku (8 of 8 chicks)
- 10/2016 – Second HAPE translocation
- 12/2016 – Second HAPE cohort fledged from Nihoku (20 of 20 chicks)
- 6/2017 – Phase III habitat restoration (~0.4 ha) with volunteer-coordinated effort

- 9/2017 – Second NESH translocation
- 10/ 2017 – Third HAPE translocation
- 11/2017 – Second NESH cohort fledged from Nihoku (18 of 18 chicks)
- 12/2017 – Third HAPE cohort fledged from Nihoku (20 of 20 chicks)

2 PERMITS AND REGULATORY PROCESS

In preparation for the predator exclusion fence construction as well as for the translocation, a total of 12 permits or consultations were needed and are summarized in Table 1 below. Permits that required extensive review or input are discussed in further detail.

Table 1: Summary of permits and consultations for the Nihoku Ecosystem Restoration Project

Permit	Responsible agency	Issued for
Coastal Zone Management Federal consistency review	DBEDT-OP	Fence construction
Special Management Area permit	County of Kaua'i	Fence construction
NEPA Compliance: Fence EA	USFWS	Fence construction
ESA section 7 consultation	USFWS	Fence construction
NHPA Section 106 consultation	USFWS/DLNR	Fence construction
Rodenticide application permit	USFWS	Predator removal
Scientific collection permit	DLNR	Translocation
Special use permit	DLNR	Translocation
HAPE and NESH recovery permit	USFWS	Translocation
NEPA Compliance: HAPE translocation EA	USFWS	Translocation
NEPA Compliance: NESH translocation EA	USFWS	Translocation
Refuge special use permit	USFWS	Translocation

2.1 Environmental assessments

A total of three environmental assessments (EAs) were prepared by Anden Consulting for this project: one for fence construction, and one each for translocation of HAPE and NESH, and these documents formed the foundation from which all other permits and consultations were based. All three can be downloaded from www.nihoku.org. Initially, project partners discussed including these activities in the Comprehensive Conservation Plan (CCP) for KPNWR, which was scheduled to go out for public review in 2012. However, as a result of delays encountered during that process, the project decided to move forward with its own EA for fence construction.

The proposed actions included in the draft EA for the fence construction were:

(1) fence construction
(2) predator eradication and monitoring within the fenced area; and

(3) native habitat restoration through invasive species removal and revegetation with native plants.

The fence construction and habitat restoration EA evaluated potential impacts associated with Alternative A, the no action alternative, and Alternative B, the proposed action, and were fully disclosed, analyzed and described in detail. The implementation of the proposed action was determined to not result in significant impacts to any affected resources. The USFWS incorporated a variety of public involvement techniques in developing and reviewing the EA. This included direct mail of an initial scoping letter to a wide variety of Federal, State and County agencies, non-governmental organizations, and individuals, several public presentations about the project, direct mail (to the scoping distribution list) inviting review and comment on the Draft EA, press releases about the project, and posting information about the project and the Draft EA on the KPNWR website. The EA was available for a 45- day public review beginning on September 16, 2013 during which time six public comment letters were received. The comments received expressed concerns over impacts to State water quality, public access to nearby sites, and introduction and spread of invasive species. Responses to the public comments were prepared and are included in the Final EA which was released in March 2014. Based on the public comments received and considered, Alternative B as described in the EA was slightly modified to incorporate those comments and a finding of no significant impact (FONSI) was published on 4 March 2014.

While the fence EA was being written and reviewed, it became clear that finalization of the KPNWR CCP was not going to occur in a timeframe that was compatible with commencement of the next stage of the Nihoku project, and so the decision was made to do separate EAs for both the HAPE and NESH translocations. The HAPE EA evaluated management actions for immediate implementation to reduce the potential for extirpation of the endangered ʻUaʻu (*Pterodroma sandwichensis*, Hawaiian Petrel, HAPE) from Kauaʻi, Hawaiʻi. Alternatives considered included:

- Alternative A (Current Management): Continuation of current management activities related to the HAPE on Kauaʻi including predator control and invasive plant removal.
- Alternative B: Continuation of current management actions as described under Alternative A, and social attraction (playing recordings of HAPE calls) would be used to lure prospecting adult HAPE to the predator-free fenced area at Nihoku. Artificial burrows also would be installed.
- Alternative C (Preferred Alternative): Included all management actions described under Alternatives A and B, and the addition of chick translocation to the predator-free fenced area at Nihoku. Proposed actions related to chick translocation included (1) collection of chicks from source locations; (2) chick care at the translocation site; and (3) monitoring for HAPE at Nihoku.

The same public engagement strategy used for the fence EA was repeated for the HAPE EA. It was available for a 45-day public review ending 31 August 2015, during which time five public comment letters were received. Responses to the public comments were prepared and included as an appendix since one of the comments was extensive. Based on the review and analysis in the EA and the comments received during the public review period, the USFWS selected Alternative C for implementation because it had a higher potential for establishing a new breeding colony of HAPE that was protected from predation by introduced mammals and birds, which would reduce the probability of extirpation of HAPE from Kauaʻi.

For NESH, the same strategy and alternatives outlined for HAPE were used. The EA was available for a 30-day public review ending 10 June 2016, during which time six public comment letters were received. Responses to the public comments were prepared and included as an appendix because, similarly to the HAPE EA, several of the comments were extensive. Based on the review and analysis in the EA and the comments received during the public review period, the USFWS selected Alternative C for implementation because it had a higher potential for (1) establishing a new ʻAʻo breeding colony at KPNWR that was within an accessible, predator-free area, adjacent to the ocean, away from utility lines and disorienting lights and (2) evaluating the feasibility of social attraction and chick translocation as species recovery techniques, which would inform future seabird management.

2.2 Special management area permit

Hawaiʻi's Coastal Zone Management Act outlines objectives, policies, laws, standards, and procedures to guide and regulate public and private uses in the coastal zone management area, which is defined to be the entire State of Hawaiʻi. Since the project area was located entirely within the County Special Management Area (SMA) along the coastline, a SMA permit was required in order to construct the fence. Since the project cost fell under the $500,000, a minor SMA permit was applied for that did not necessitate a public hearing. The final determination was that the project would be consistent with the objectives and policies outlined in Hawaiʻi Revised Statutes (HRS) Chapter 205A-2 because it would preserve the quality of coastal scenic and open space resources and minimize adverse impacts on coastal ecosystems. The NERP would also be consistent with the Special Management Area guidelines outlined in HRS Chapter 205A-26 as it is proposed solely for the benefit of native wildlife and habitat. An approved SMA permit was issued in May 2014.

2.3 Federal recovery permit

Recovery permits are issued by the USFWS to qualified individuals and organizations to achieve recovery goals of ESA listed species, including research, on-the-ground activities, controlled propagation, and establishing and maintaining experimental populations. The information obtained from activities covered under recovery permits provides the USFWS with a better understanding on how best to conserve, manage, and recover federally protected species. Since the translocation of NESH and HAPE was being conducted by PRC, a non-profit non-governmental entity, a recovery permit was required from the USFWS for the action. The translocation plan and EAs for both species were used as the foundation for this permit. The permit request was approved in October 2015 for HAPE and amended in 2016 to include NESH, at which point the USFWS issued a biological opinion on the expected impacts of issuing the permit.

2.4 Land-owner permits

Various land-owner permits were required during this project to work on or remove birds from areas for translocation since the source colonies were spread out and located on federal, state and private lands. Formal special use and scientific collection permits were obtained from DLNR for both removing the birds and for working in a Natural Area Reserve. Similar permits were obtained from KPNWR for work on the Refuge and for translocating a NESH chick from within the existing Refuge colony to Nihoku. For private landowners, such as the National Tropical Botanical Garden, written agreements were put in place that explained partner roles and expectations as well as the biological impact of removal of birds for translocation.

2.5 Archaeological surveys and section 106 consultation

Steps were taken to determine the cultural and historical significance of the project area: (1) preparation of an Archaeological Assessment in May 2013 by Cultural Surveys Hawaii; (2) review of a previous Archaeological Inventory Survey completed in 1989 for KPNWR expansion; and (3) informal consultation with a variety of organizations and individuals who might have information regarding the project area, including the Kīlauea Point Natural History Association, Office of Hawaiian Affairs, and State Historic Preservation Division. The 2013 Archaeological Assessment met the State's requirement for an archaeological inventory survey (per HAR 13-13-276). No cultural resources were found within the project's area of potential effect during the survey. The full Archaeological Assessment was included as Appendix C in the fence environmental assessment. Although no specific resources were found in the project area during the archaeological survey, the general area is of cultural significance and has been treated as such.

2.6 Conclusions

While the number and length of permits required for this project was extensive, given the logistical constraints of moving two different listed species between sites with three different landowners, all partners showed a strong willingness to collaborate in order to achieve the goals of the project. Future projects should attempt to incorporate anticipated future management actions (such as fence construction and translocation) into existing planning documents to avoid the need for multiple EAs. In hindsight, it might have been preferable to combine all three EAs into one document, or into the CCP, but the timing would have delayed implementation of certain stages of the project. Given the declining populations of the seabirds, it was determined that delay associated with combining all the actions into one compliance document could potentially foreclose the possibility of action, hence the decision to move forward with independent NEPA documents.

3 PUBLIC OUTREACH

3.1 Introduction

In order to maintain good relations and transparency with the public, partners, and stakeholders, it is paramount that a well-planned outreach effort be included in a restoration project of this scale. Because the concepts for this project have their origins off-island (first in New Zealand and then at Kaʻena Point on Oʻahu), it also presented an important educational opportunity to introduce the public to contemporary methods in island conservation which were largely unfamiliar to many Kauaʻi residents.

3.2 Approach

The strategy taken with this project, given its close proximity to a residential neighborhood, was face to face interactions with the community as well as development of various educational materials to ensure all stakeholders were reached. Starting in 2013, PRC gave annual public talks at the Princeville Library to update the public on the project. From 2012-2014 PRC staff met with Refuge staff twice monthly to brief USFWS staff on the project; from 2014-2017, meetings with staff have been on average every two months with frequent e-mail and phone updates. PRC has also given annual tours to the project site for the public during Refuge week in October and numerous stakeholder tours on an on-demand basis. In addition to holding public meetings and site visits, PRC and KPNWR have attended several community meetings to discuss both the fence construction and seabird translocations, and all have been positive. Numerous press releases have been issued by all partners on this project resulting in dozens of popular media articles on the project with the majority of these documents permanently posted on the project website.

For the EA processes specifically, the USFWS incorporated a variety of public involvement techniques in developing and reviewing the EA. This included direct mail of an initial scoping letter to a wide variety of Federal, State and County agencies, non-governmental organizations, and individuals, several public presentations about the project, direct mail (to the scoping distribution list) inviting review and comment on the Draft EA, press releases about the project, and posting information about the project and the Draft EA on the KPNWR website. Upon finalization of each EA, a press release was done to announce its completion.

For the translocations, each year at least one press release has been done either at the beginning or end of the translocation season, to announce the project and its results for the year. Finally, project biologists have given numerous scientific presentations on the results of this work at various local, national and international scientific meetings.

3.3 Materials produced

- Posters – posters describing the project background, purpose, and outcomes were presented at the Hawaiʻi Conservation Conference and Pacific Seabird Group meetings, and one remains on permanent display at the KPNWR visitors center.
- Brochures – project brochures were developed and printed during the scoping phase of the project and then revised once translocations had been conducted. They were

formatted for both tri-fold printing and as two page pdf documents that can be downloaded from the project website. Each year approximately 200 brochures are distributed directly and many more are downloaded from the website.
- Videos – three short (< five minute) videos have been produced on the project by ABC; one on the translocation itself, one on the habitat restoration, and one on the artificial burrow design. All videos are permanently posted on the project website.
- Website – a dedicated project website (www.nihoku.org) was developed and is described below.

3.4 Website and blog posts

In 2016, a website was developed exclusively for the project at www.nihoku.org. The purpose of the website was to provide an easy to access location for project information and to house increasing numbers of important documents, such as EA's, project FAQ's and blog posts. The website is broken down into the following pages:

- Home – description of project objectives and background
- Threats – threats to NESH and HAPE and justification for the project
- Solutions – explanations of predator exclusion fencing, habitat restoration, managing montane colonies, and social attraction/translocation
- Partners – a list of partners, their missions, and roles in the project
- Downloads – project fact sheets, photo galleries, videos, EAs, and new releases
- News – current announcements, select media articles, blog posts
- Support Nihoku – a donation page directing individuals to either ABC or PRC's page

The website is updated monthly to add information and keep it current.

Blog posts were done regularly starting with the HAPE translocations in 2015 with 3-4 per year being published. ABC took the lead on writing and publishing these posts on their website and their length ranges from 500-1000 words. During the translocation period, frequent Facebook posts by all partners resulted in tens of thousands of views.

3.5 Summary

In the first five years of this project, the combined outreach efforts reached several thousand people directly through public presentations and one on one contact. Indirect reach through popular media articles is thought to be approximately three million individuals per year based on analyses provided by ABC through an independent contractor. In short, widespread media coverage has resulted in broad public awareness and support for this project, and hopefully, about the conservation status of these species as a whole.

4 Biological Monitoring

4.1 Introduction

Monitoring of biological resources before and after predator removal is crucial for measuring and demonstrating the benefits and effectiveness of predator fencing as a management technique compared with traditional fencing and predator control methods (VanderWerf et al. 2014). However, the types and amount of information gathered can vary dramatically depending on the site, budget, and goals, and in some cases there may be insufficient baseline data available to make the desired comparisons. In such cases, the use of simultaneous treatment and control sites located inside and outside areas that have been fenced and from which predators have been excluded can be used to measure the effects of predator fences. In the case of Nihoku, sufficient baseline data already existed for some taxa (seabirds), but was lacking for others (plants and invertebrates) to make these comparisons. Extensive monitoring of a variety of taxa therefore was undertaken prior to fence construction in order to document the effects of the predator exclusion fence.

To facilitate consistent, repeatable monitoring for a variety of species, a geo-referenced, 50 m interval grid oriented on magnetic north was installed (Figure 2), with points marked by white PVC with a 10 cm reveal. The rationale for selecting a 50 m grid was to provide an adequate number of replicates within the fenced area (N=14) for ecological comparisons and to have appropriate spacing for rodent bait stations, since 50 m is the average home range size for Black Rats (VanderWerf et al. 2014). The grid consists of stations inside the fence (experimental) and outside the fence (control) spaced every 50 m, resulting in 14 points inside the fenced area and 10 outside. With the exception of bird species, all biological monitoring was done using these grid points.

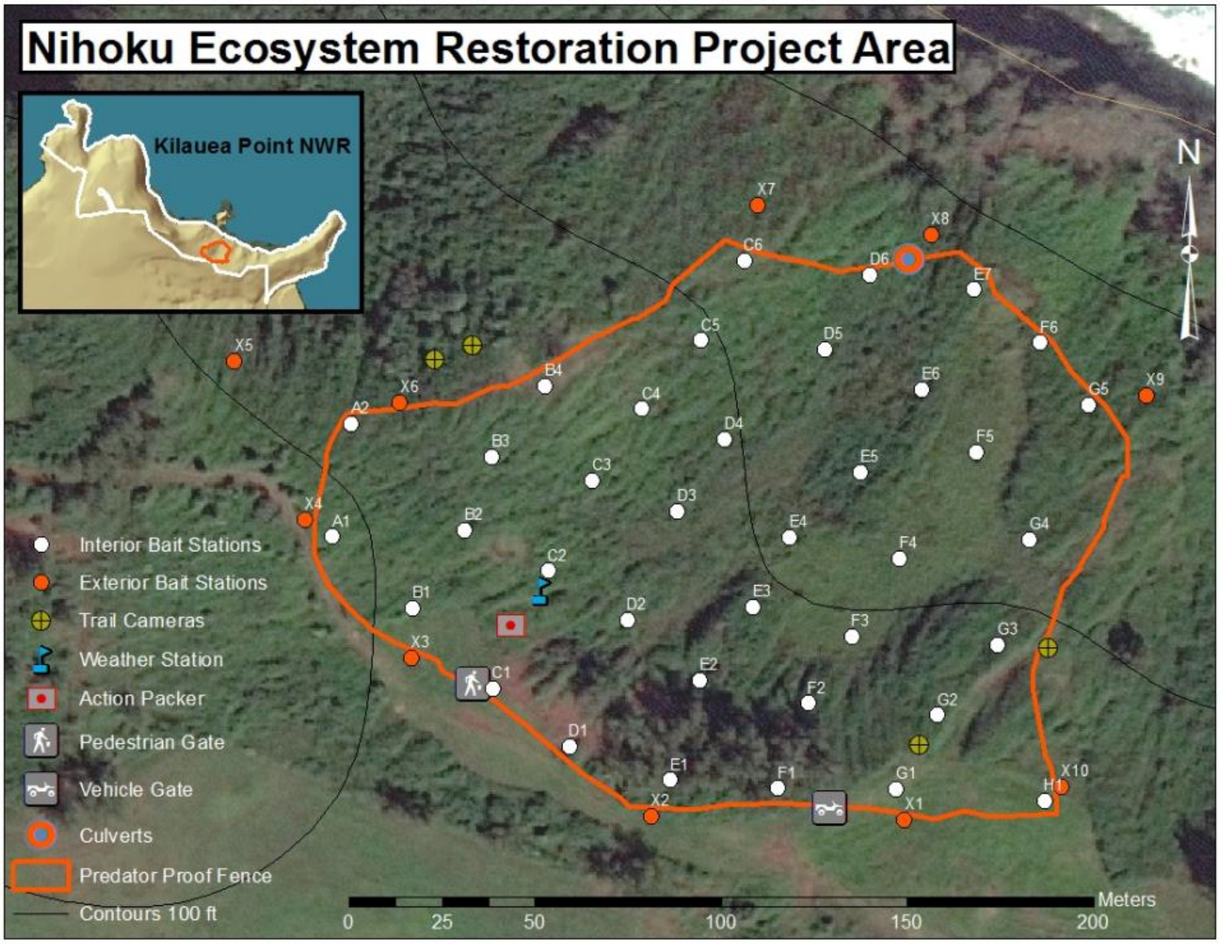

Figure 2: Nihoku fence monitoring grid with final fence line.

4.2 Methods

Seabird and Nēnē

All native bird species within the project area were, and continue to be, monitored in order to gather data on native species present and their reproductive success prior to predators being removed. Monitoring of existing Nēnē and Albatross nests in the project area was undertaken by conducting nest searches throughout the area and by recording the band number of individuals encountered. When nests were found, their contents were noted and the fate of the chicks was followed through to fledging.

During the NESH and HAPE breeding season (April - November), evening auditory and visual surveys for nocturnal seabirds were undertaken in 2013 and 2014 at six points in the project area. Surveys were done for two hours beginning at dusk following techniques outlined in Raine et al. 2017. In addition to the auditory surveys, automated recording units (song meters SM2+, Wildlife Acoustics) were deployed in two locations in June to collect recordings of any nocturnal seabirds present. One unit was deployed within the project site, while the other was placed for comparison within the small Newell's Shearwater colony at KPNWR. At the existing NESH colony, auditory playback was turned off once per week to allow the song meter to record NESH activity. Recorders were programmed to record one min of auditory data of every five minutes from dusk until dawn. The song meters were collected in November at the end of the breeding season. During both auditory and song meter surveys, Barn Owls were monitored to determine the predation risk of the incipient colony at Nihoku.

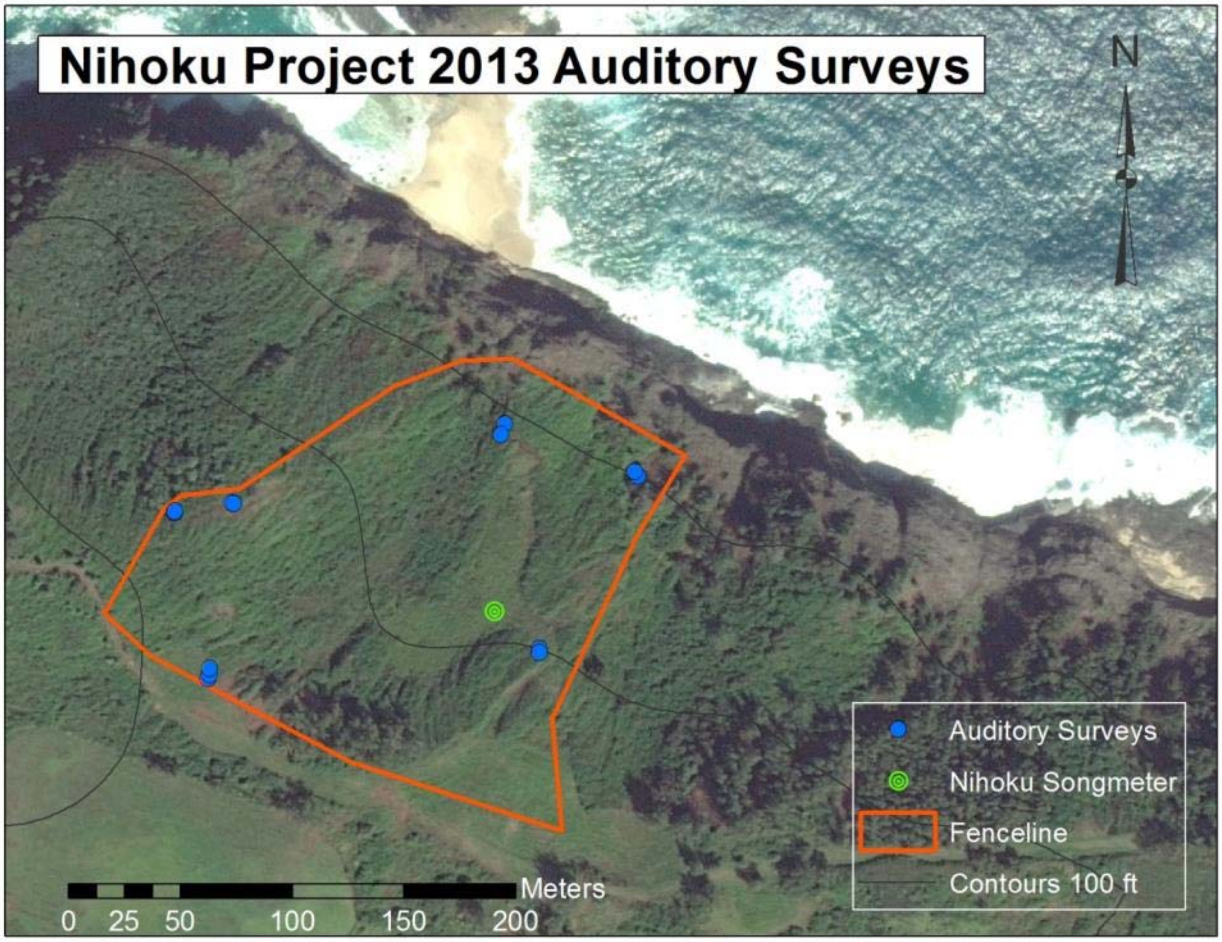

Figure 3. Auditory and song meter survey locations at Nihoku, with initial proposed fence line.

Detecting changes in bird population size associated with predator removal may require many years of monitoring, and it may be more feasible to detect changes in other population parameters, such as nesting success. Bird populations may respond slowly to management, and it may require several years for birds to begin using an area or for increased rates of recruitment to result in detectable population increases. For birds that have been extirpated, simply their presence in the area following predator fencing would demonstrate success.

Invertebrates:

Invertebrates are a relatively inconspicuous but extremely important component of native ecosystems. Native invertebrate communities provide integral ecological services, including pollination services and nutrient cycling, without which most Hawaiian plant species could not exist (Howarth and Mull 1992). Changes in abundance, diversity, and species composition of the invertebrate fauna at a site may help to indicate improved ecosystem functioning.

Invertebrates were monitored in December 2012, February, June, and September of 2013 using a variety of methods designed to capture animals that used different foraging methods (e.g., winged vs. not) and in different levels of the habitat (e.g., leaf litter vs. arboreal). Sampling was done at each grid point (N=24), and all insects gathered were stored in ethanol for future sorting. Methods for each of the sampling techniques are described below.

<u>Pitfall Traps</u>

For ground-dwelling species, pitfall traps are an effective passive sampling method (Spence and Niemela 1994). To install pitfall traps, a shallow hole was dug in the ground and a small cup or bowl filled with propylene glycol (anti-freeze) was used both as an attractant and preservative. The lip of the container was positioned to be even with the surrounding ground to ensure that crawling invertebrates fell into the container and could not escape. The Nihoku pitfall traps were baited and deployed for three days. Following trap collection, specimens were transferred into vials with 70% ethanol for storage.

<u>Yellow Pan Traps</u>

Many insects are attracted to the color yellow, a trait which is often used to facilitate their collection (Neuenschwander 1982). A yellow pan trap is a quick and easy way to catch specific types of invertebrates that are attracted to the color yellow (e.g., flies, wasps, and beetles). At Nihoku, a shallow yellow bowl was placed into a small hole so that its rim was level with the ground. The bowl was filled with water, and several drops of detergent were added to break the surface tension. The traps also collected invertebrates not attracted to yellow, intercepting them in the same manner as the pit-fall traps. Following collection of the pan traps, specimens were transferred to 70% ethanol for storage.

<u>Yellow Sticky Cards</u>

Sticky cards traps are used to collect the adult stages of flying insects (e.g., flies, gnats, shoreflies, leaf miners, winged aphids). Sticky cards consisted of 4"x 14" yellow card-stock, folded in two, coated with a thin veneer of a sticky paste (Seabright Laboratories Sticky Aphid Whitefly Trap without lure). At each gridpoint, a trap was hung from vegetation at the top of the canopy approximately 2-5 m from the ground, where it was visible to flying insects for up to three days. Sticky cards were collected and wrapped in plastic wrap for long-term storage.

<u>Vegetation Beating and Sweep Netting</u>

Vegetation beating and sweep netting are some of the most effective approaches for collecting a broad assortment of invertebrates from vegetation. To survey woody shrubs or trees, a 1x1 m canvas drop cloth, or "beat sheet", was laid under the vegetation targeted for sampling. The vegetation was then shaken by hand, or "beaten" with a sweep net handle, to dislodge invertebrates present on the foliage. Specimens were then collected by hand or with forceps. Since herbaceous vegetation, grasses, and some shrubs did not lend themselves to beating, they were sampled with sweep nets. A canvas insect net was swung across vegetation, knocking off and capturing invertebrates present on the foliage. Those specimens were also collected by hand or with forceps. Fifteen beats and fifteen sweeps were completed at each of 24 sampling points within the Nihoku Ecosystem Restoration Project area.

<u>Ant monitoring</u>

Ants had a separate protocol to monitor for their presence because they are a documented threat to nesting seabirds in Hawaiʻi (Plentovich et al. 2017). At each of 24 sampling gridpoints spaced at 50-m intervals, two index cards were baited, one with spam and the other with peanut butter and honey to attract ant species with different dietary preferences, and left for two hours following protocols developed by the USFWS. Each card was then collected, the number of ants was noted, and the species were identified. Sampling was conducted five times in seasonal (quarterly) intervals. Species that were not easily identifiable were sent for further analysis to external entomologists.

Invertebrate specimens were identified to species where possible and invertebrate abundance was measured as a total number of individuals and/or biomass captured per trapping interval/ collection effort. Abundance of invertebrates in different feeding guilds (herbivores, detritivores, nectarivores, predators, parasitoids, etc.) will be examined to look for shifts in ecosystem functioning before and after predator removal.

Plants

Plant surveys were conducted using a hybrid plot – point-centered quarter design for density of trees and shrubs. Around each grid point, a 5m radius circular plot was constructed by laying out two 10 m long strings at marked in the center at 5 m, in North to South and East to West orientations, with markers intersecting, creating 4 quadrants.

Plant species were identified and recorded inside each quadrant in terms of percent cover by stratum. Quadrants were divided into three strata, or layers: Ground Cover, Shrub Layer, and Canopy Cover. Ground cover consisted of all plants less than 10 cm tall, and also included leaf litter, bare soil, and bare rock, totaling 100%. Shrub layer consisted of all plants between 10 centimeters and 2 m tall, and sometimes included open space, totaling 100%. Canopy layer consisted of all plants greater than 2 m tall, and open canopy, totaling 100%. Canopy height was measured using a clinometer/rangefinder, or by hanging a tape measure from the tallest tree within the 5 m plot.

Slope and aspect were measured at the center point using a compass with a clinometer arrow. Topographic position was recorded based on a list of pre-defined descriptors: Level, Lower-slope, Mid-slope, Upper-slope, Escarpment/Face, Ledge, Crest, Depression, and Draw. Soil texture and color were recorded, according to the Unified Soil Classification System and the Munsell Soil Color Chart index (http://soils.usda.gov/education/resources/lessons/color/).

Surveys were conducted quarterly in 2013, and an overall Refuge inventory was done March 19-22 by the Refuge in addition to the plot design so that we had an idea of percent cover, species assemblages and soil type.

Soil and weather

Soil samples were collected at each of the 24 survey points. Using a metal trowel, soil was collected from within 1 m of each gridpoint by inserting the trowel to a depth of up to 15 cm from the surface (generally only 5-10 cm) and rotating 360 degrees. Loose soil was placed in a labeled Ziploc bag and stored at room temperature for future analysis.

A Davis Instruments Vantage Vue weather station was installed within the project site on June 27, 2013 to passively collecting weather data. Data was downloaded monthly and batteries replaced in the wireless console approximately once per month. Weather data was collected from June 2013 to February 2015.

4.3 Results

Seabirds, Nēnē and owls:

In 2014, a total of two Nēnē nests and five Laysan Albatross nests were found within the proposed fence area (Figure 4). Neither Newell's Shearwater nor Hawaiian Petrel were detected during auditory surveys or with song meters, but numerous Wedge-tailed Shearwaters were detected, from birds nesting outside the project area (Figure 5). In addition, two Kermadec Petrels (*Pterodroma neglecta;* KEPE), which breed in New Zealand and the southern hemisphere, were seen regularly flying through the project area, vocalizing frequently and potentially doing courtship flights. While there are not any records of Kermadec Petrels nesting in Hawaiʻi, the behavior they exhibited during these surveys suggested they may be prospecting for nesting locations if they were not nesting already. This species has been recorded in previous years at KPNWR, and has occurred regularly at KPNWR throughout the breeding season for the last four years. Barn Owls were detected sporadically in small numbers.

Figure 4. Native bird nests recorded at Nihoku from 2012-2014, with initial proposed fence line.

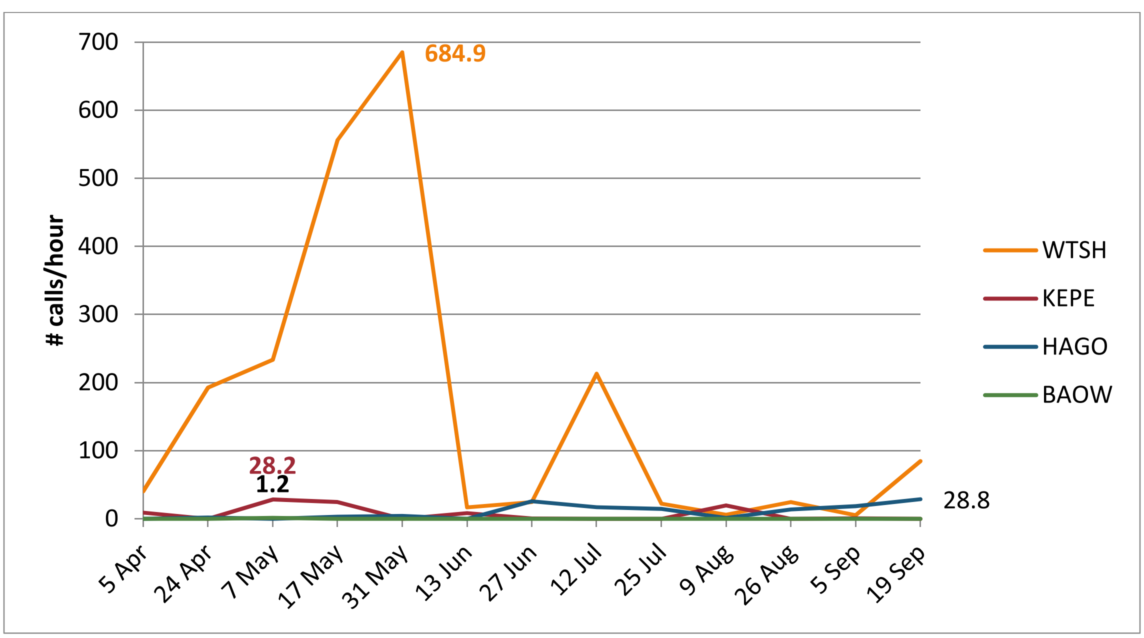

Figure 5: Frequency of avian species detected during evening auditory surveys from six points within the Nihoku fence area. Highest average detections per hour are labeled in corresponding

colors. WTSH = Wedge-tailed Shearwater; KEPE = Kermadec Petrel; HAGO = Hawaiian Goose (Nēnē); BAOW = Barn Owl.

Invertebrates

General insect collections were sent to external entomologists for storing and sorting at a later date. Ants were all identified to species (Figure 6).

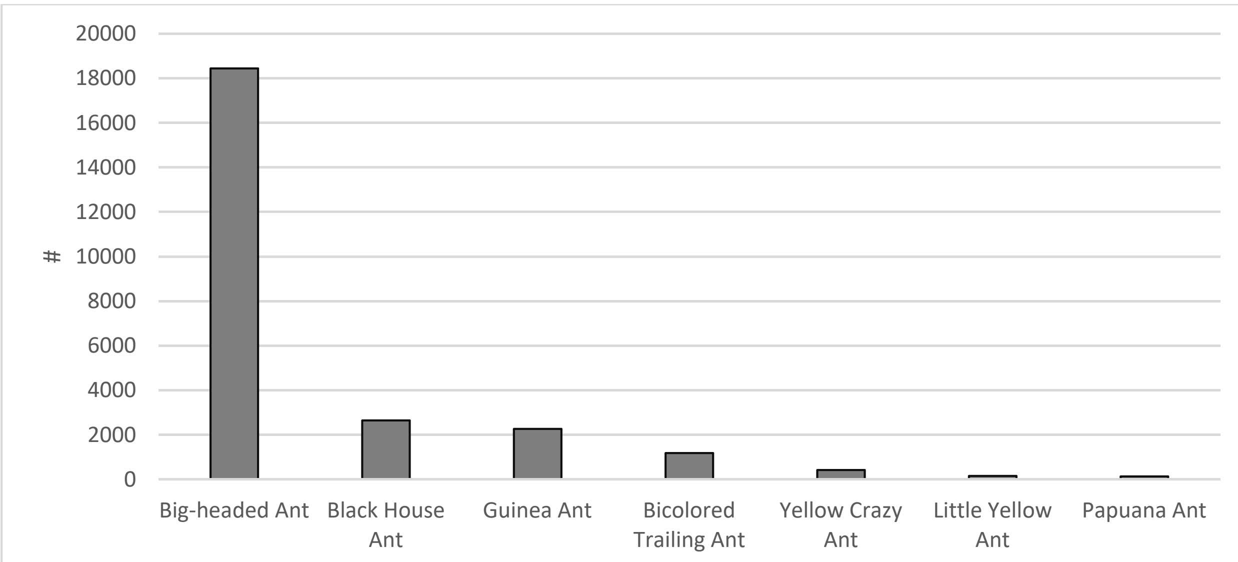

Figure 6: Species composition and relative abundance of ants at Nihoku.

No evidence of Little Fire Ants (*Wasmannia auropunctata*) or Tropical Fire Ants (*Solenopsis geminata*) were observed at the site, but one unidentified ant sent to entomologists was identified as *Solenopsis* sp. Fire ants are known threats to seabirds and were a concern for this project. Yellow Crazy Ants (*Anoplolepis gracilipes*), another ant known to threaten certain seabird species, were detected at Nihoku on several grid points. The recorded density of Yellow Crazy Ants is likely lower than the actual density, as this species is extremely agile and difficult to collect. At least one incident of colonization by Leptogenys Ants (*Leptogenys falcigera*) was witnessed, but not collected during ant sampling.

Plants:

A total of seven native plant species were detected (Figures 5-7), none of which were dominant within survey plots and none of which were listed species. The most common native species were naupaka (*Scaevola taccada*), ‘ūlei (*Osteomeles anthyllidifolia*), ‘akoko (*Euphorbia celastroides var. stokesii*), and hala (*Pandanus tectorius*). Introduced *Schinus terebinthifolius*, commonly known as Christmas berry or Brazilian pepper tree, was by far the most abundant plant species in all three layers, and occupied >50% of shrub and canopy layers within the vast majority of survey plots (Figures 5-7). No rare or endangered plant species were detected that year. Across strata and 3 seasons of data collection, only 5.1% of total plant density recorded was native.

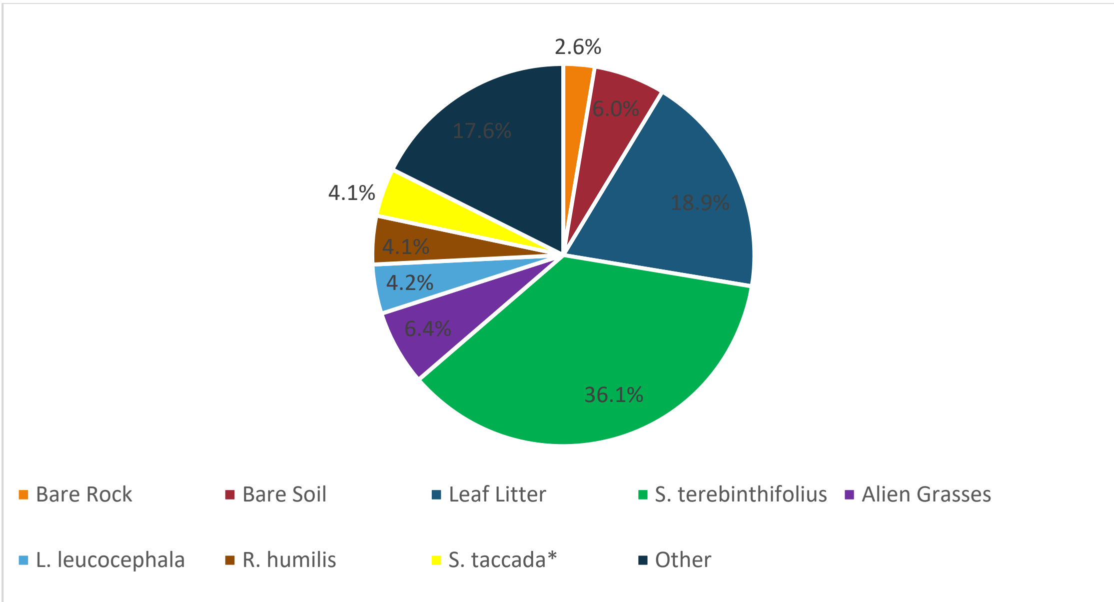

Figure 7: Pre-restoration plant species composition of ground cover stratum at Nihoku.

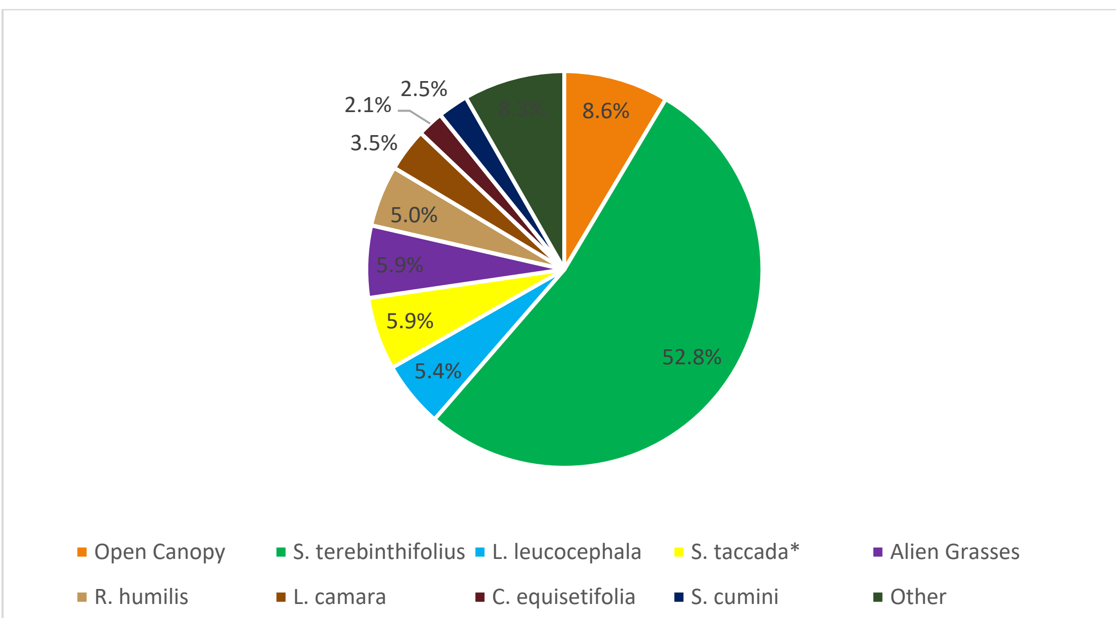

Figure 8: Pre-restoration species composition of shrub cover stratum at Nihoku. Note that >50% of this stratum was occupied by *Schinus terebinthifolius*.

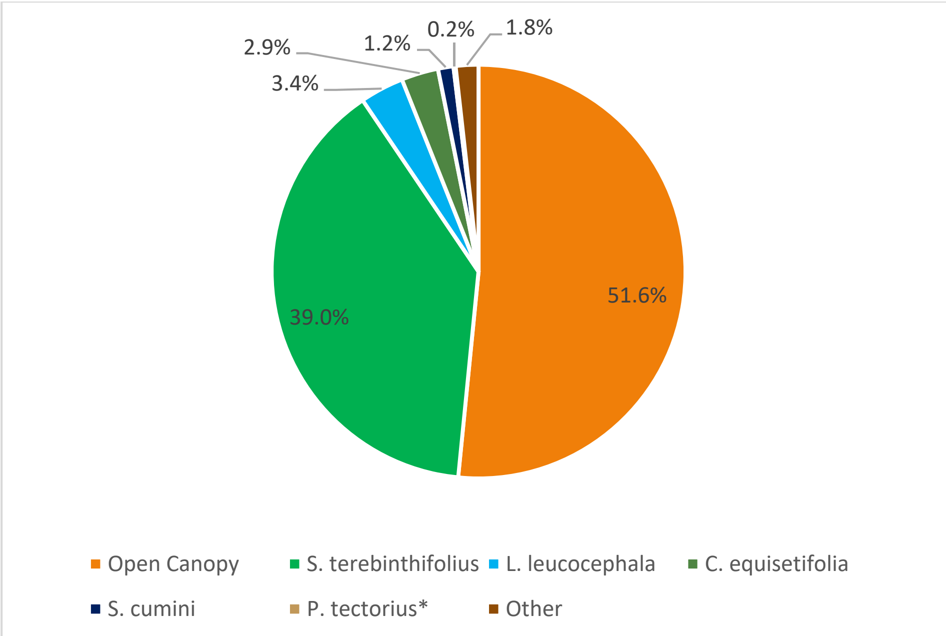

Figure 9: Pre-restoration species composition of canopy cover stratum at Nihoku. Note that only 0.2% of this stratum was occupied by native species.

Weather

From June-March, the Nihoku based weather station logged an average of 3.82 mm of rain per month, with peaks in the winter months.

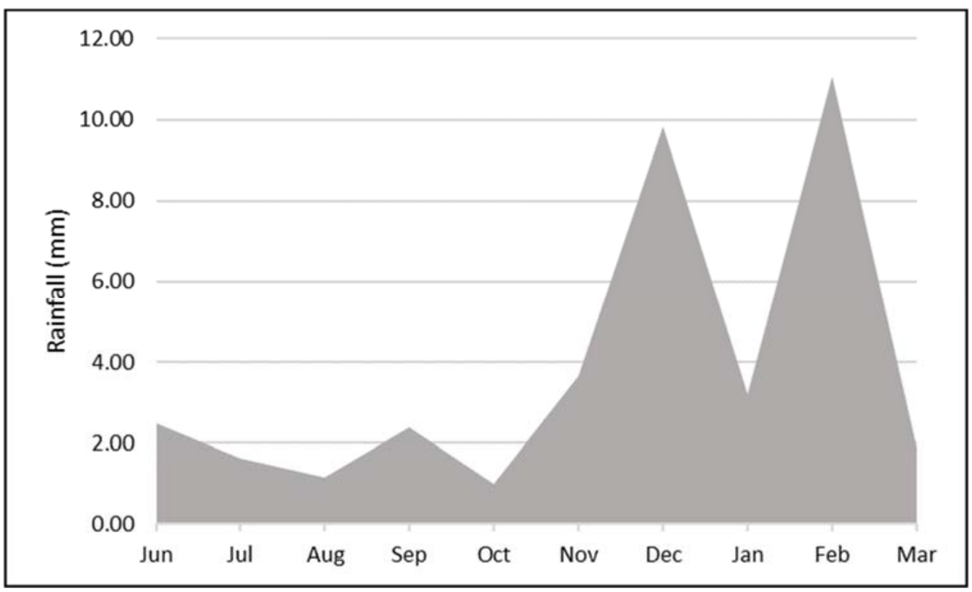

Figure 10: Average rainfall by month at Nihoku project site

5 PREDATOR FENCE SPECIFICATIONS

5.1 Introduction

The fence design, materials, and construction specifications are summarized in Table 2 and described in detail below. These were based on the specifications required to completely exclude the mammal species found on Kauaʻi, as determined by extensive research in New Zealand and trials in Hawaiʻi (Day and MacGibbon 2002, Burgett et al. 2007), and previous experience constructing predator fences in Hawaiʻi (Young et al. 2012, Young et al. 2013). The goal was to create an effective barrier against all known mammalian pests known to occur on Kauaʻi, as well as potential future pests (such as mongooses).

Table 2: Summary specifications of Nihoku predator exclusion fence.

Nihoku fence statistics	
Length	2,132 feet; 650 m
Area enclosed	6.2 acres; 2.5 ha
# pedestrian gates	1
# vehicle gates	1
Project manager	Pacific Rim Conservation
Builder	JBH Ltd
Date completed	September 2014
Cost/ft	$137.43
Cost/m	$451
Materials cost	$193,403.34
Labor cost	$99,596.66
Total cost	$293,000.00

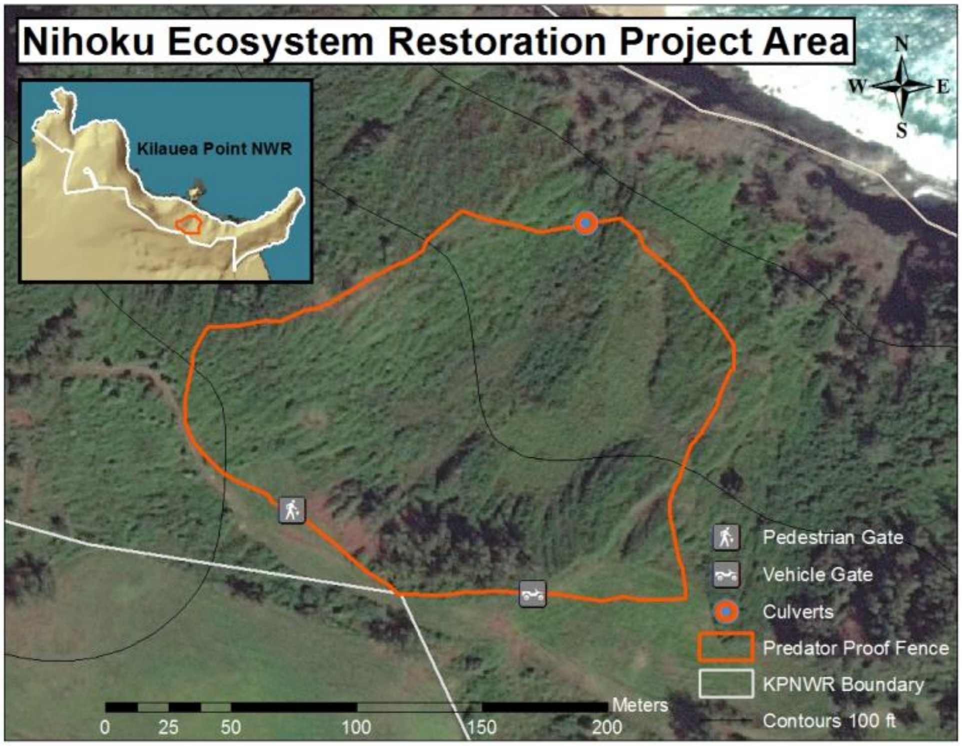

Figure 11: Final Nihoku predator fence alignment.

Figure 12: Nihoku fence photograph facing northeast.

5.2 Cost

The total cost for the 650m fence was $293,000. Of those costs, $99,596.66 was for labor and $193,403.34 for materials. The price per meter was $451/m. The cost was virtually identical to that of the Kaʻena Point fence, but an increase in quality due to the materials selected (Nihoku was all stainless steel vs. multiple metals at Kaʻena).

5.3 Fence design

The predator exclusion fence design has three main elements: fence posts, mesh (including the underground skirt), and rolled hood (see Figure 13 below). The fence posts provide the structural strength and framework on which other components are mounted, and was made of 2 inch square stainless steel posts and stainless steel fastenings. Posts were spaced two meters (6.6 feet) apart, with one meter of the post set below ground and two meters protruding above ground. Marine grade (316) stainless steel mini chain link mesh with an aperture of 10 x 8 millimeters was attached to the entire face of the base fence, and was also used to form a skirt of horizontal mesh at ground level, to prevent predators from tunneling under the fencing. The mesh extends from the top of the posts to just below ground level, while the skirt extends 300 millimeters from the fence and is buried 5-10 cm (2-4 in) underground.

The fence is high enough (2m) that animals, including cats, cannot jump over it, has a curved hood to prevent animals from climbing over the top, small aperture mesh (10 x 8mm) to prevent animals from squeezing through, and a skirt under the ground to prevent animals from digging underneath. Since the area where the fence was placed was not accessible to the public, a single door gate design was used for pedestrian gates instead of the double door gates at the public access Kaʻena Point fence (Young et al. 2012). Additionally, a vehicle gate was installed at Nihoku to allow heavy equipment into the area for restoration activities. All materials, including hood and posts, were 304 grade stainless steel with the exception of the mesh, which was 316 stainless steel. Materials were purchased directly from Pest Proof Fencing Co. in New Zealand and shipped to Hawaiʻi.

A single culvert was installed at the bottom (north) end of the fence where there was a natural ephemeral drainage feature. Despite little evidence of regular running water, it was clear that water did occasionally flow during periods of high rain. A three-foot-wide PVC tunnel was installed under the fence line, and cinderblock tiles were used to fill in the space around the culvert. Once it was complete, the fence was built overtop of the culvert, cemented in place, and a mesh screen was installed over the culvert openings to ensure it remained pest proof.

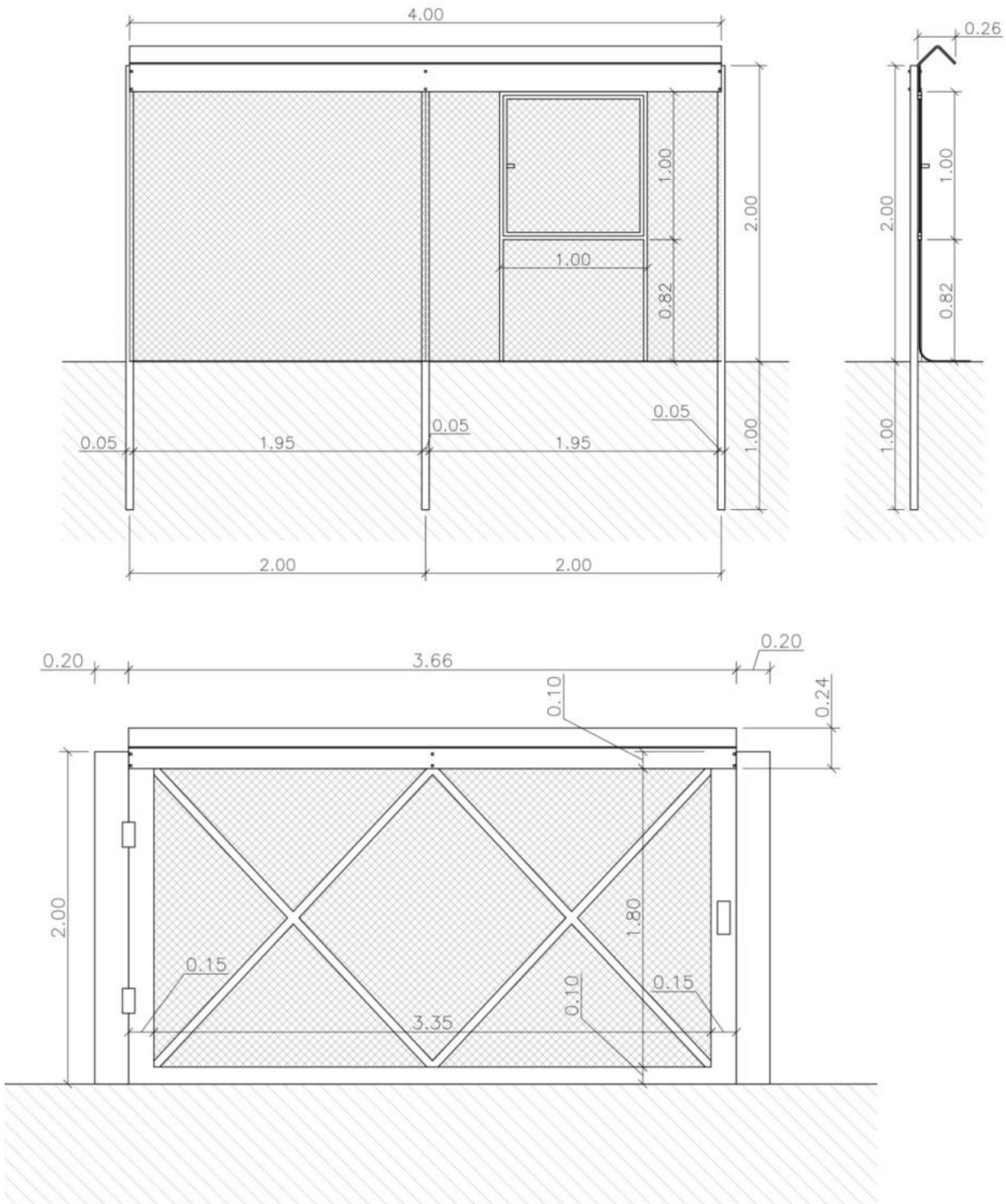

Figure 13: Predator exclusion fence technical specifications. Measurements are in meters.

Figure 14: Nihoku pedestrian gate (left) and culvert (right). The culvert is shown during construction. Fence exterior is on the right; mesh was placed over the inside of the culvert opening to prevent debris from getting into the culvert and to prevent rodents from entering.

5.4 Contract and selection of fence vendor

Three local fence contractors were approached and asked to provide cost estimates for construction of the fence at Nihoku. In the end, only one contractor submitted a bid (the other two declined to bid) and that contractor, JBH Ltd., was selected. JBH Ltd. assisted Xcluder in constructing the Kaʻena Point predator fence and thus was familiar with the technology and specific needs of such a project.

Construction needed to occur within a narrow three-month summer window in order to avoid the Nēnē breeding season at Nihoku, and having an explicit contract with deadlines was needed. Based on past experiences of contracting for other fences, the following were added as clauses (in addition to those outlined in Young et al. 2012):

1. Contractor was to supply all fasteners in the same metal grade (304 stainless) as the fence components. This clause gives the contractor some flexibility to select the best fastener for each scenario and thus reduce construction time.
2. Contractor was required to remove all construction waste.
3. Monetary penalties of $500/day were written into the contract for not completing the project on time, given the time constraints related to the Nēnē breeding season.
4. Re-negotiation of the contract price (up or down) if the final fence length varied by more than 5% of the estimated length.

5. Withholding of 50% of the contract value until completion and final inspection of fence have been signed off by an independent third party verifying that the fence has been built to specification.
6. A 30-day window to fix any construction deficiencies.

For this project, the contractor was also required to provide a complete parts list, including item description, material, manufacturer, and part number in a spreadsheet, and also a written maintenance manual, repair kit parts list, and one day of on the ground training for managers. The combination of these contract items, coupled with suggestions made in Young et al. 2012 made for a relatively smooth construction process.

5.5 Construction logistics

Fence construction began in June 2014 and was completed in September 2014. A construction window was established during contract negotiations tied to weather, road conditions, Nēnē nesting seasons, and ideal rodent removal periods. Permit regulations also dictated construction logistics to a certain extent.

Immediately prior to construction, the fence contractor was given oral as well as written instructions by project staff on appropriate behavior on the Refuge as well as training on endangered species identification. The area where machinery was allowed was clearly flagged, and any native plants or other notable features were flagged to prevent damage to the landscape. Contractors were notified of authorized walking trails, were required to bring their own portable toilet facilities, and were required to pack out any waste daily. Finally, a physical copy of all permits was given to the contractor and they were required to have these with them at all times on the job site and abide by the conditions set forth in the permits at all times.

The project consisted of the following stages of work:

- Clearing of fence-line (removing vegetation from a 3-4-meter wide swath, with machinery if possible or else by hand with chainsaws and hand tools)
- Fence platform formation (earthworks, drainage works, and culverts) with use of heavy equipment
- Installation of posts
- Attachment of hood sections
- Attachment of mesh (including ground pinning/cementing)
- Installation of culverts
- Installation of gates

For the most part, construction went as planned with no major issues encountered. Following construction, rubber water guides were installed along areas of the fence line with the steepest slope to divert water flow away from the fence and minimize erosion where bare soil was exposed. Pili grass (*Heteropogon contortus*) seed was also planted in these areas to enhance soil stabilization.

5.6 Maintenance

Based on discussions with other predator fence project managers, annual maintenance cost for materials is estimated to be 1% of the initial cost of the fence (e.g., $150,000 material cost = $1,500 per year in parts), plus labor. The extra 5% of materials from the original order can be used for repairs for the first few years. The staff time required to monitor the fence varies, but a monthly inspection on foot is recommended, with repairs on an as-needed basis.

To date, maintenance issues have been relatively minor for this fence both as a result of improvements made to the design and materials, and because it is still relatively new. The cost estimates provided above have been relatively accurate, and perhaps an overestimation of the initial maintenance costs. The two issues that have been encountered were with the vehicle gate and the steep slopes around the culvert. The ground under the gates settled after construction which put stress on the gate hinges and made it difficult to close. This was fixed by adjusting the hinges and ensuring everything is properly lubricated.

For future projects, the following are recommended for designing and implementing a fence monitoring program. While it may not be possible to implement all of these suggestions at all sites, they provide a foundation of the factors that should be considered when managing predator exclusion fences.

• An individual within the agency responsible for management at the site should be established as the primary point of contact for each fence. This individual would be in charge of scheduling maintenance and monitoring visits (even if they are not the one performing them) and would serve as a point of contact for anyone who needs to report a breach or any other relevant observations on the fence.

• A risk analysis of each fence should be undertaken regularly (e.g., during each regular monitoring visit) to identify possible areas of weakness. This analysis should identify possible reinvasion sites, such as at culverts, gates, overhanging trees, steep slopes, areas prone to high winds or rock falls, or in areas of public access. These sites should be inspected carefully during maintenance visits.

• To assist in having breaches reported in a timely manner, signs should be placed at high-risk areas and access points that provide contact information for whom to call in the event that a maintenance issue or predator is noticed. Fence posts also should be tagged with a unique number so that anyone reporting a breach can identify the location easily (e.g. fence panel #180). These can either be engraved into the fence posts or added as separate tags or labels.

• Storing fence repair supplies in the vicinity of high-risk areas can help to facilitate rapid repairs, particularly for mesh damage, which can often be fixed quickly by hand. Using the woven mesh in particular has an advantage in that a single spare wire can usually be woven into the fence to repair a hole.

• All fences need to be physically inspected on a regular basis. How regularly this is done depends on the risks prevalent on the site. Inspection may need to be monthly for some fences vs. quarterly for others. Specific recommendations for each fence are made in the implementation plan below. Factors that affect risk of breaches and pest reinvasion include:

public access and potential for vandalism and accidental damage; the nature and size of animals adjacent to the fence; proximity, extent, and size of adjacent trees; regularity and severity of flooding; regularity of people entering and leaving the fenced area; difficulty in eradicating pests within the fence following a reinvasion; and the value and sensitivity of the resources being protected by the fence.

• A physical fence inspection should be undertaken on foot where possible. Walking along the fence line allows the observer to view and inspect the fence closely and directly. Inspections should be periodically undertaken from both sides of the fence. When inspecting, there are four components to look at: hood, posts and stays, skirt, and mesh. The hood should be examined for excess lichen growth which can facilitate cats climbing over, corrosion at seams, attachment points, bends, and for scratches indicative of cats attempting to jump over. If scratches are noticed, the area should be examined to determine if there are jump points. Posts and stays should be examined for corrosion and loose attachments. Mesh should be examined for breaks in welds or links, corrosion or abrasion, and separation at the seams and attachment points. The skirt should be examined to ensure that there aren't any punctures, it is secured to the ground, not eroded underneath, and that the lip is not curling up and allowing pests to dig under.

• The duration between physical inspections can be increased by the installation of electronic surveillance systems. Solar-powered systems can detect open gates and fence damage, the location along the fence, and the extent of the damage and report it back to a control board or phone electronically. These are optional features that can notify managers immediately of an open gate or tree-fall, but do have additional costs and maintenance associated with them.

• When a fence breach occurs, it is important that any pests that enter the fence are detected quickly. If a breach goes unnoticed for some time and there is no pest detection program in place, it may become necessary to re-eradicate the pest species from the entire fenced area. The best way to detect pest intrusions is to establish a network of bait stations, traps, or tracking tunnels around the inside of the fence line and also either a grid of bait stations throughout the protected area or at least scattered stations in strategic locations. Such a grid of bait stations or traps was established previously to achieve complete pest eradication; retention of the station grid will assist with the early detection of any re-invaders. The grid need not be active at any given time, but having infrastructure in place will help to ensure a timely response.

• For budgeting purposes, it is estimated that during the first five years of the fence, minimal materials cost will be needed as extra materials ordered at the time of construction will be used for physical repairs. After year five, fence managers at other sites budget up to 1% of the capital fence cost per year to dedicate towards maintenance.

5.7 Design improvements

While the design for the Nihoku fence was conceptually the same as that for the Kaʻena Point fence, several changes were made (in addition to the gates described above) to reduce maintenance needs, cost, and facilitate construction.

The mesh used at Nihoku was a mini-chain link compared to the welded rectangular mesh used at Kaʻena Point. While both have comparable openings and are tested to exclude mice, the advantages of the chain link were that:

1. It came in 10m long rolls that could be woven together at vertical seams thus making the entire fence seamless and reducing weak points where two panels were joined together.
2. The rolls were 2.35m wide, which was wide enough to form the vertical fence and the horizontal underground skirt, thereby eliminating the horizontal seam that was present on the Kaʻena fence where two 1-m wide rolls were attached together to form a 2m high fence. This seam was particularly problematic at Kaʻena Point and has required constant maintenance.
3. Chain link is much more flexible to allow for contouring along hillsides and is less susceptible to breakage because it is not as taught as the woven mesh. This flexibility also eliminated the need for tension wires to hold the stiff welded panels taught.

Minor modifications also were made to the hood design. The main change was to use an uncoated hood product, and to eliminate the curved lip under the hood edge which collected water at Kaʻena Point. Despite costing the same, the new hood design used at Nihoku is more effective, requires less maintenance, and makes the fence slightly higher (since it curves up rather than down) thus increasing its effectiveness. An uncoated hood was requested for this project so that corrosion could be monitored more easily. The coated hood at Kaʻena Point was not stainless steel and rusted through within four years. However, since it was coated, the rust was not apparent until it had corroded all the way through the hood. The Nihoku hood, aside from being 304-grade stainless steel to increase its resistance to corrosion, was left uncoated so that any rust progression could be monitored more closely. However, a 200-m section of the Nihoku fence eventually was painted dark green after a neighboring resident complained of the bright metal reflection that could be seen off the hood into his home.

In addition to the contract and design changes already discussed, future fences could be improved by using treated wooden posts to allow for attachment flexibility with the mesh attachment, and by having a double door vehicle gate rather than a single large gate. The stress put on the single set of hinges across the 12-foot span for the vehicle gate was high. By having two doors that join at the center, less stress would be placed on the hinges, which would reduce maintenance and make the door easier to operate.

6 PREDATOR MONITORING AND ERADICATION PLAN

6.1 Introduction

All mammals in the Hawaiian Islands except the Hawaiian monk seal (*Monachus schauinslandi*) and the Hawaiian hoary bat (*Lasiurus cinereus semotus*) were introduced by people, some intentionally for food, pets, or biocontrol agents, and others as accidental stowaways (Tomich 1986). Because Hawaiʻi is so isolated from continental areas, the native plants and animals that evolved in the islands are naïve to mammalian predators and often lack defenses against them (Salo et. al. 2007, Sih et. al. 2009, VanderWerf 2012). Polynesians colonized the Hawaiian Islands about 800 years ago (Rieth et. al. 2011) and brought with them several destructive predators including the Pacific rat (*Rattus exulans*), domestic dog (*Canis familiaris*), and domestic pig (*Sus scrofa*) (Kirch 1982, Burney et. al. 2001). Introduction of alien predators accelerated with the arrival of Europeans starting in 1778, including the black or ship rat (*R. rattus*), Norway rat (*R. norvegicus*), domestic cat (*Felis silvestris*), small Indian mongoose (*Herpestes auropunctatus*), house mouse (*Mus musculus*), and European wild boar.

Predators, particularly black rats, are the single greatest threat to seabirds worldwide (Jones et. al. 2008). Feral cats and small Indian mongooses are known to be serious predators of seabirds on O`ahu and elsewhere in Hawai`i (Hodges and Nagata 2001, Smith et. al. 2002). Although mongoose do not appear to be established on Kauaʻi yet (Duffy and Capece 2014; Duffy et al. 2015), cats are a significant predator of Newell's Shearwater and Hawaiian Petrel on Kauaʻi, including in the source colonies for the translocation project (Raine et al. 2017a&b). Rodents, including black rats and Pacific rats, are known to prey on seabirds throughout the Hawaiian Islands, including Kauaʻi (Fleet 1972, Woodward 1972, Smith et. al. 2006, Raine et. al. 2017). Rats and house mice (*Mus musculus*) have also been documented to consume native plants, their seeds, and invertebrates (Shiels 2010). There are many examples in which eradication or control of predators has resulted in recovery of native species in Hawai`i (Hodges and Nagata 2001, Smith et. al. 2002, VanderWerf and Smith 2002, VanderWerf 2009, Marie et al. 2014, VanderWerf et al. 2014) and around the world (Côté and Sutherland 1997, Butchart et. al. 2006, Howald et. al. 2007). Three non-native predatory mammal species are regularly present at Nihoku: feral cats, black rats, and house mice.

Feral cats are present at Nihoku year-round and have caused substantial damage to seabird populations at KPWNR in the past. Dietary analysis of feral cats caught at Kaʻena Point on Oʻahu (a similar seabird colony) indicates that both seabirds and rodents are significant components of their diet (Lohr et al. 2013). Rats and mice are thought to be important ecosystem modifiers at Nihoku due to their consumption of prey at all levels of the food chain, from plants through birds. Rodents and cats therefore were the primary target of the Nihoku predator removal plan. Experience from other eradication attempts suggested that while mice do not pose the greatest risk for ecological restoration, they can be the most difficult species to eradicate due to their small home ranges, which require a higher bait application rate (VanderWerf et al. 2014).

The objectives of designing the predator removal program were to select the most effective method(s) available while considering the pest species present, the tools legally available for use, and the timeline and funding available. It is possible that the methods chosen do not reflect the most universally effective methods employed in other countries or states, but were the ones that were most feasible given the scope and constraints on this project. It should be noted that Barn Owls are a known predator of both NESH and HAPE, but will not be excluded with the fence and thus will be controlled on a semi-permanent basis. To inform these efforts, predators were monitored quarterly for two years in order to obtain an understanding of population densities and approximate home range sizes of species within the Nihoku project area.

6.2 Pre-eradication pest monitoring methods

Rodent monitoring was conducted from 2012-2014. Population data were collected by spacing rat snap traps (in Nēnē-exclusion boxes) on grid points (N=24) and mouse live traps on all grid points and then every 25 m between grid points (N=42). Traps were set seasonally (quarterly) for three nights after three nights of pre-baiting with peanut butter to acclimate them to the presence of the traps. Beginning in winter 2013, tracking tunnels were set quarterly for 24 hours with peanut-butter baited ink cards during the pre-baiting period.

To estimate rodent home range size, live traps were deployed during the November and March monitoring events to capture live rodents for tracking purposes. Haguruma brand live cage traps were used for rats and Eaton brand repeater mouse traps were used for mice. Both trap types were baited with peanut butter. All rodents captured were sexed, weighed, and identified to species. A small spool of white thread was glued to the back of each rodent captured. Spools used with rats weighed less than 2g and held up to 200m of thread; much smaller spools were used for mice. The end of the thread was tied to a piece of vegetation and the rodents were released. Two or three days later), GPS tracks of the path of the rodents were taken by following the thread. Maximum distance travelled was measured for each animal, and substrate and habitat type also were noted. From those distances, a minimum convex polygon was calculated within ArcGIS. Minimum convex polygons draw the boundaries of a home range from a set of location data is to construct the smallest possible convex polygon around the data.

Beginning in March 2013, cat monitoring and trapping was undertaken to determine their density using Bushnell trail cameras paired with 10 Havahart traps set at strategic locations (Figure 15). Trap locations were selected based on repeatedly noted cat sign (footprints, scat, predation). Traps and cameras were set four nights per week and baited with a rotation of vienna sausage, dried cuttlefish, pureed 'potted' meat, and soft cat food.

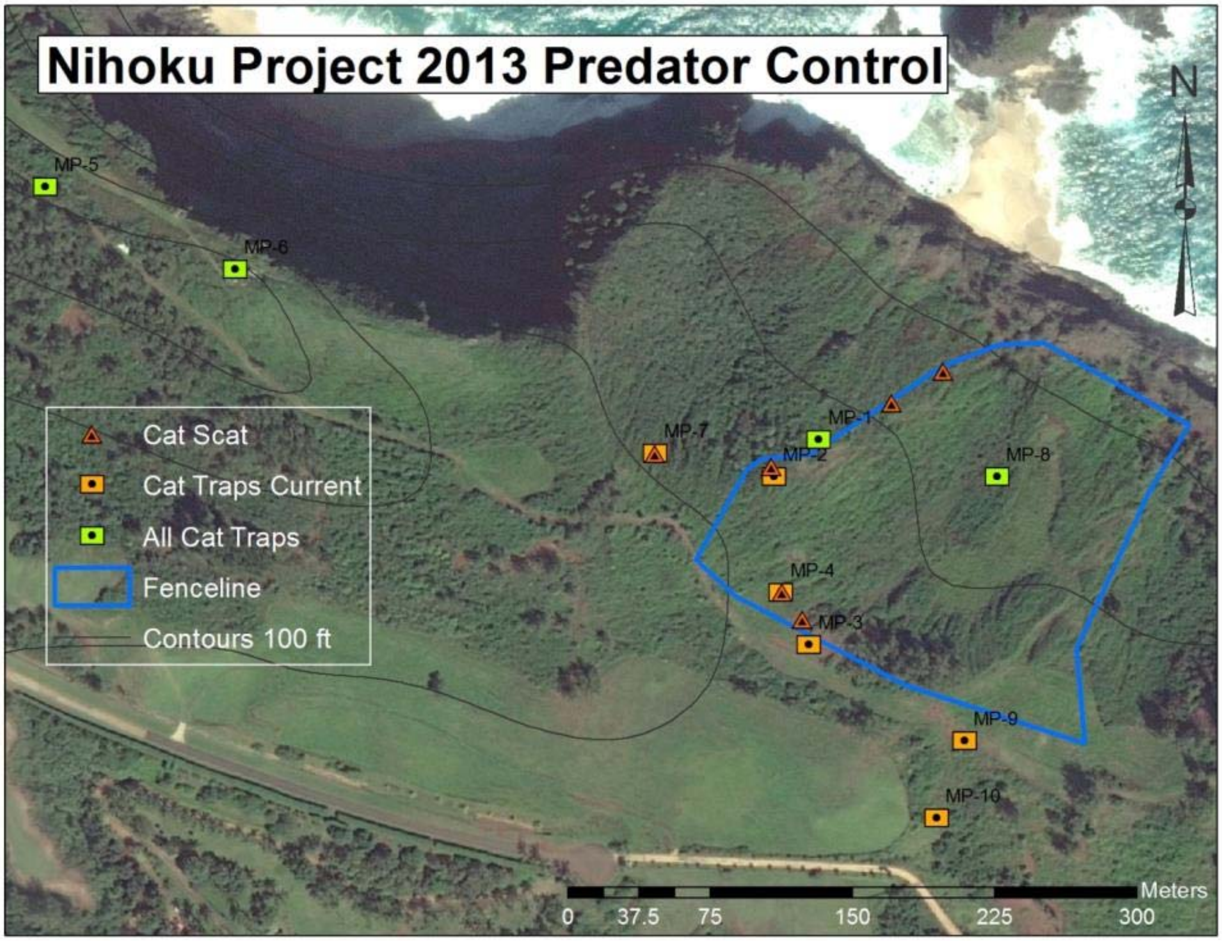

Figure 15: Nihoku cat control points.

6.3 Monitoring results and discussion

The rodent species detected were house mouse and black rat; no Polynesian rats were found. The catch rates varied seasonally, with the low point for mice in the winter and the low points for rats in the spring and summer (Figure 16). Despite the seasonal variation of both species, both measures of relative abundance were low indicating that densities likely were low.

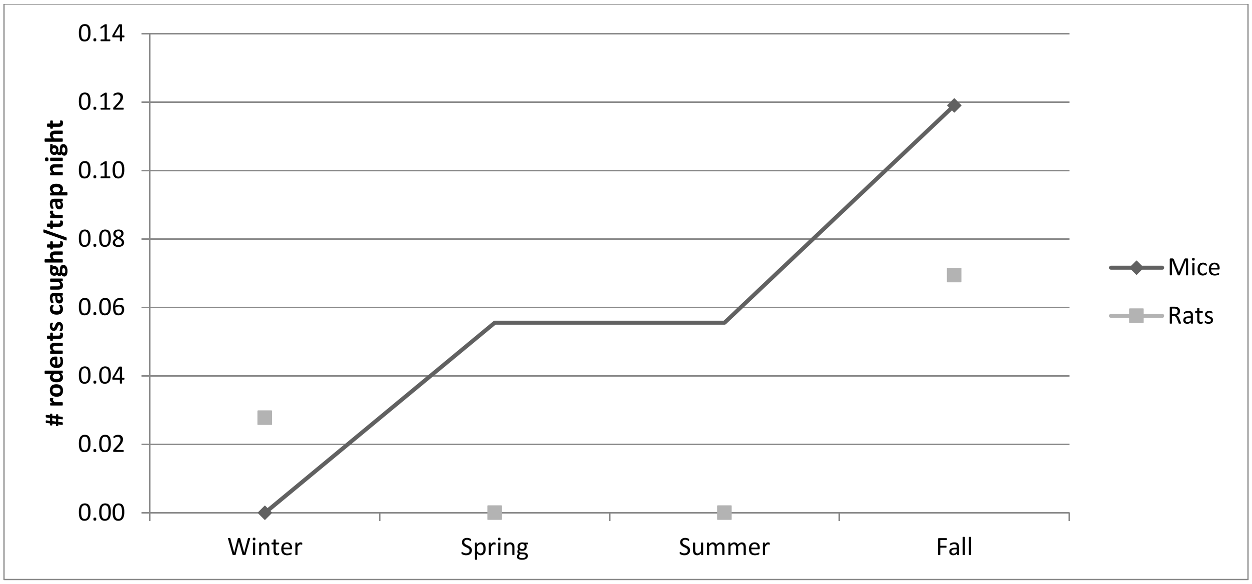

Figure 16: Frequency of rodent captures/ trap night by season.

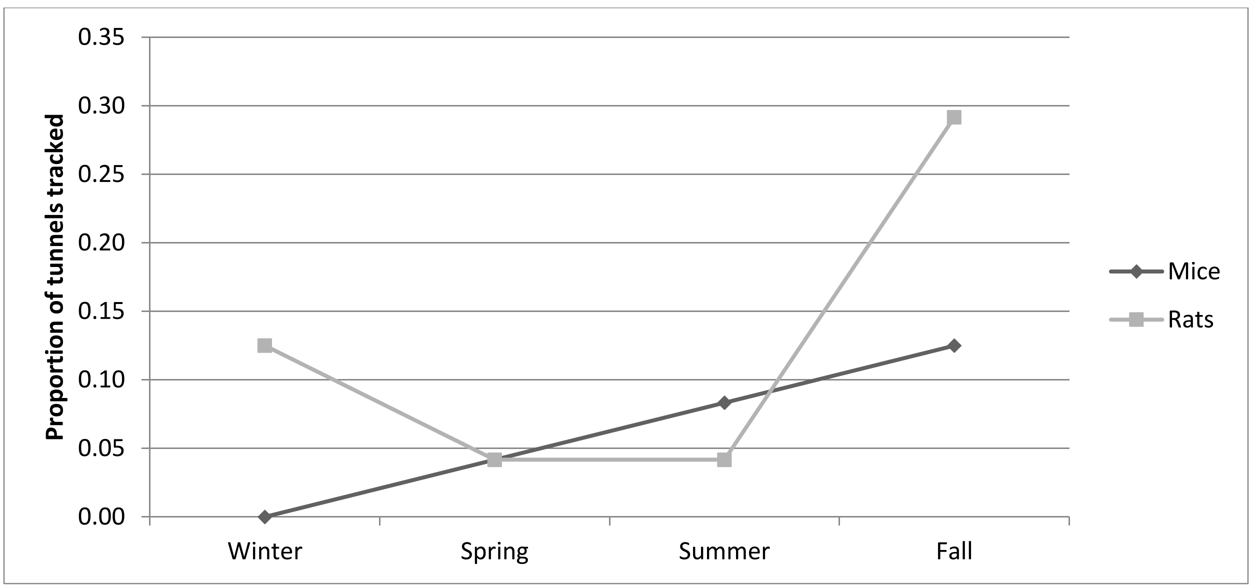

Figure 17: Frequency of tracking tunnel rodent detections by season**.**

A total of nine mice were tracked for home range estimation; two in the fall and seven in the spring. Rats were more difficult to catch in the live traps; three rats were tracked during the fall event and only one was tracked during the spring. Mice traveled an average maximum radius of 14 m (46 ft) with the spools of thread (range 7.1-29.4 m; Figure 18), resulting in an approximate home range size estimate of 0.015 ha (1565 ft^2; Figure 19). Rats traveled an average maximum radius of 28m (92 ft), for an estimated home range size of 0.021 ha (2214 ft^2). For eradication purposes, this corresponds with trap or bait station spacing of 12 m (40 ft) for mice and 15 m or 50 ft for rats, which would be a high-density trap placement. Typically, rodents in a high density situation will have smaller home ranges, however, in this case, the home ranges appear to be small and the densities low. It is possible that the poor habitat in the area has contributed to low densities for rodents and does not reflect high rates of intraspecific competition.

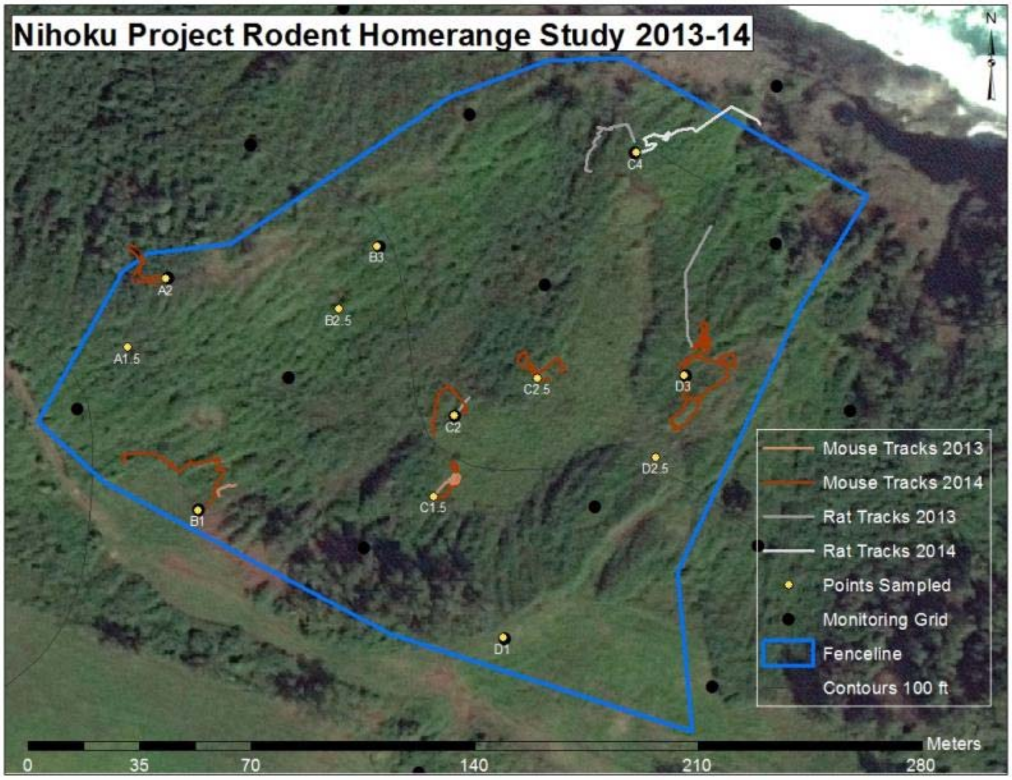

Figure 18: Rodent travel distances within the proposed fence area.

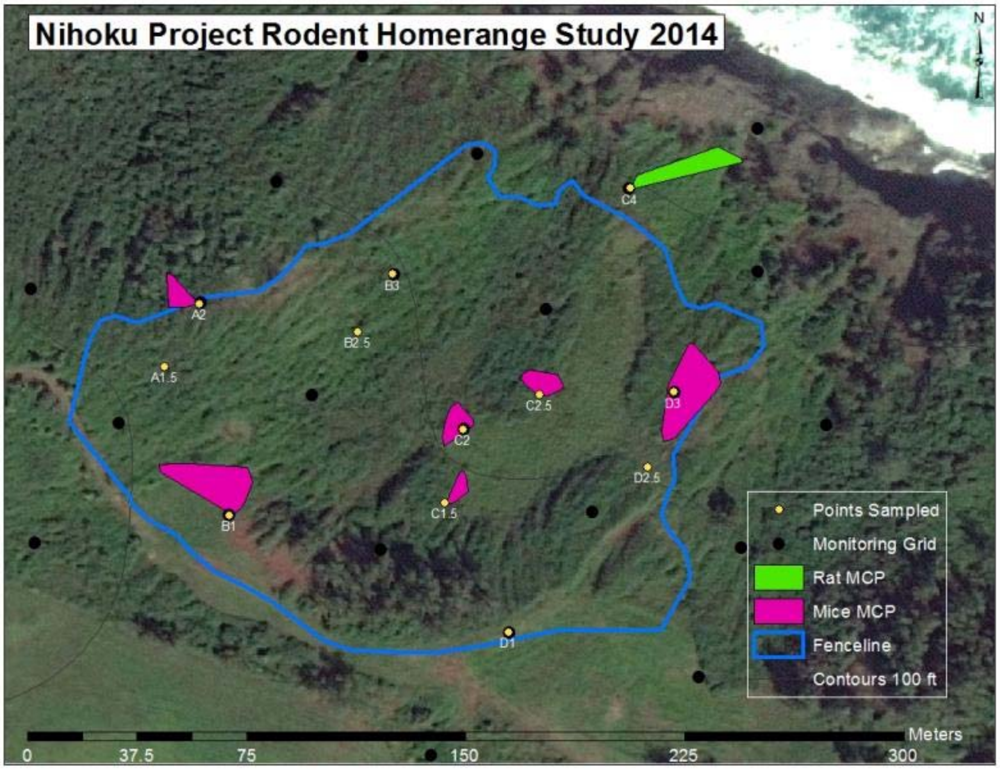

Figure 19: Minimum convex polygons depicting approximate rodent home range sizes within the final fenced area.

Seventeen cats were trapped, resulting in 0.0175 cats/trap night (17 cats/970 cage trap nights), indicating that cats were at low density in the area. No seasonal patterns were detected in cat abundance and cats were present year-round. Necropsy of three of the cats revealed moderate fat content, a full stomach containing small feathers, hair, insect exoskeleton, a few small bone fragments, fish pieces, and worms, and that specimens were not reproductively active. Feathers did not appear to be from seabirds; however, stomach contents were frozen and stored for possible further inspection.

6.4 Eradication plan outline

Based on our data, the most effective methods of predator removal were determined to be:

1) Live trapping for any remaining cats;

2) Diphacinone poison in bait stations on a 25-m grid for black rats and mice (only 50-m spacing is required for rats); and

3) If baiting alone did not result in eradication of mice, a combination of the 25-m diphacinone bait station grid and mouse traps on a 12.5-m grid.

Since the rodent tracking data indicated there was rodent breeding year-round, control operations were scheduled to begin immediately after fence construction to avoid any predation on Nēnē or Albatross nesting in the fenced area. Since the fence was completed in the fall, which corresponded to the lowest productivity point in the mouse breeding season, and a decline in rat abundance, this was a logical choice.

Diphacinone has been used to control rodents in Hawaiian coastal habitats (VanderWerf and Young 2014, F. Duvall pers. comm.) and was used to successfully eradicate Pacific rats on Mokapu Islet off of Molokaʻi (Dunlevy & Scarf 2007) and black rats at Kaʻena Point (Young et al. 2013). Diphacinone also has been used to eradicate black rats in a variety of locations worldwide (see Donlan et al. 2003, Witmer et al. 2007 for examples), though it appears to be less effective than brodificoum, particularly for mice (Parkes et al. 2010). However, diphacinone was the only poison approved for conservation purposes in Hawaiʻi, and thus was the only option available for this project. The decision to wait to conduct trapping for mice was based on the relatively low density of the animals, the low risk for being seabird predators, and the possibility that prolonged application of bait in bait stations would be sufficient.

Rodents were targeted with Ramik mini-bars® (HACCO Inc., Randolph, Wisconsin, USA) containing 0.005% diphacinone placed in tamper-resistant Protecta ® plastic bait stations (Bell Laboratories, Madison, Wisconsin, USA) to shield them from rain and reduce the risk of poisoning to non-target species. Bait stations were placed in a 25-m grid pattern throughout the fenced area and filled with up to 16 1-oz blocks per station. Bait stations were serviced twice per week during the first month, and after that frequency was adjusted based on levels of take to ensure that an adequate supply of bait was available at all times. Eradication was achieved for both rodent species in a five-month period with bait alone.

7 Habitat Restoration

7.1 Introduction

Ecological restoration is the process of assisting the recovery of ecosystems that are damaged, degraded, or destroyed (Society for Ecological Restoration International 2004). For the Nihoku project, the goals of the restoration were framed in the context of building an ecological community comprised of native species, based on the limited historical knowledge of the coastal and lowland plant communities of Kauaʻi outlined in Bruggeman and Castillo (1999). More than one third (300+) plant species in Hawaiʻi are listed as threatened or endangered under the Endangered Species Act and species found in coastal shrublands and low elevation forests are particularly rare due to the higher degree of development and human habitation along coastlines. Only 11% of lowland mesic and dry native plant communities remain intact on Kauaʻi, compared to 22% for all of the Hawaiian Islands combined (The Nature Conservancy 1998). Thus restoring and providing safe areas for coastal native plants on Kauaʻi is of high priority to preserve these rare ecosystems.

KPNWR encompasses 65 ha (160 ac) of coastal sea bluff and, while managed largely for seabirds and Nēnē, contains important remnant coastal ecosystems (USFWS 2016). The Nihoku project site is composed of approximately six acres within KPNWR, just south of Makapili Rock and east of Crater Hill. The botanical surveys conducted at Nihoku, and described above, revealed that virtually the entire area (95%) was comprised of non-native species and was devoid of any burrow nesting seabirds. As a result, a restoration plan was developed in order to ensure the area was made suitable for both HAPE and NESH to be translocated there and to provide optimal forage for Nēnē. What is presented below are the techniques used and results obtained after implementation of that plan.

Purpose:
The goals of the restoration effort for Nihoku were to make the habitat suitable for currently nesting bird species, and to make the habitat suitable as a translocation site for NESH and HAPE by removing invasive species and out-planting with native species. This project also accomplished the following Refuge specific restoration goals (Bruegmann and Castillo 1999; USFWS 2016):

- Protect, enhance, and manage the coastal ecosystem to meet the life-history needs of migratory seabirds and threatened and endangered species;
- Restore and/or enhance and manage populations of migratory seabirds and threatened and endangered species.

Site characteristics
The Nihoku project site faces the ocean, on sloping land (averaging 22% slope, ranging to nearly 40% slope) above steep sea cliffs. The elevation range of the project site is approximately 42-102 m (140-335 ft) above mean sea level. The U.S. Department of Agriculture, Natural Resources Conservation Service (NRCS) conducted a soil survey for an approximately 8-acre area surrounding the project site, in which the vast majority of the project area is composed of

soils categorized as Lihue silty clay, with the remaining area made up of rock outcrop (NRCS 2013). The project area receives approximately 150 cm (60 in) of annual rainfall, with higher rainfall during the winter months (Giambelluca et al. 1986). This is supported by 189 days of data collected at the Nihoku weather station (avg. 0.16 inches/day, est. 59.81 inches/year). There are no natural waterways, such as streams, within the project site; only swales that appear to have intermittently flowing water under high rainfall conditions. The Pacific Ocean is adjacent to the project area at the base of Northern steep cliffs.

Plant composition in the immediate project area was 95% invasive species, with Christmas berry being the dominant species at >50% cover across all canopy levels. Native plant species present include naupaka (*Scaevola taccada)*, ʻūlei (*Osteomeles anthyllidifolia)* and hala (*Pandanus tectorius)*; no listed native species were present. Most vegetation at the site was low in stature (<3m in height) and aside from a small grassy patch in the center, relatively uniform in composition, particularly in the canopy strata. While this site was being used by a small number of breeding Nēnē and Laysan Albatrosses, it is not being used by any burrowing seabirds as it likely is not suitable habitat for them in its current state. In planning for the ideal characteristics of the site for both Nēnē and seabirds, attention was paid to the current habitat used by each species.

Seabird and Nēnē habitat preferences

The breeding habitat of extant Newell's Shearwater populations described by Ainley et al. 1997 are characterized by steep (65˚) slopes with densely matted uluhe fern (*Dicranopteris linearis*) at higher elevations (525-4000'). Several fossil records of this species exist at low elevation indicating they once nested closer to the coastline (Pyle and Pyle 2017), but the majority of fossil evidence is at higher elevations than the project site. At KPNWR, the nesting pairs of NESH (thought to have descended from a cross-fostering experiment) breed in a combination of artificial nest boxes placed under vegetation (typically naupaka) and in naturally excavated tunnels under hala and naupaka leaf litter. Their current distribution and habitat 'preferences' are thought to be an artifact of range constriction as a result of predation and habitat destruction, i.e., only the most inaccessible colonies are left and the current nesting site characteristics reflect this rather than their true preference.

Hawaiian Petrel habitat preferences are described by Simons et al. (1998) as being sub-humid, subalpine dry habitat with <10% vegetation cover. On Kauaʻi they are found typically found in steep montane areas, where they nest under native species such as uluhe & ʻōhiʻa (*Metrosideros polymorpha*). Fossil evidence indicates that Hawaiian Petrels were once one of the most abundant seabird species in the Hawaiian Islands with numerous colony sites at low elevation (Olson and James 1982a, 1982b, Monitz 1997). Even more so than NESH, their current distribution and habitat characteristics are likely an artifact of a significantly reduced population size as a result of human consumption, habitat loss, and the introduction of mammalian predators. Our limited ability to observe habitat preference by these species in an environment free from such pressures may suggest that what we deem to be optimal habitat is merely all that's left.

In numerous seabird translocation projects undertaken on related Procellariform species in New Zealand over the last twenty years, the problem of actual vs. artificial habitat preference has been addressed by re-creating the physical condition of the burrows themselves (length, depth, temperature, substrate, and humidity) and canopy cover (open, shrubby, full canopy etc.) as much as possible at the sites where birds have been translocated, but not worrying extensively about the precise plant species composition. Many of the sites in New Zealand that were visited as a training exercise for this project leave non-native understory grass species for easy maintenance, and focus on the larger shrub/canopy layer when undertaking restoration, if restoration is done at all. As such, we feel that the approach taken at Nihoku of partial restoration was adequate to prepare the site for seabird translocations, and has the added benefit of improving the habitat for existing native bird species while reduced maintenance needs, such as mowing/weeding.

Adding to the complexity of the restoration at the site is the fact that it must also serve as forage for Nēnē in addition to nesting habitat for seabirds. Habitat types frequently used by Nēnē at KPNWR include grasslands dominated by introduced species e.g., saltgrass (*Distichlis spicata*), Kikuyu grass (*Cenchrus clandestinus*), open-understory shrublands (e.g., naupaka, koa haole (*Leucaena leucocephala*)), and sea cliffs (USFWS 2016). Nēnē build nests on the ground, usually under woody and herbaceous plants with an open canopy. Nesting habitats range widely but generally are associated with woody vegetation. Species composition varies by availability; in lowlands on Kauaʻi both native (e.g., naupaka, pōhinahina) and non-native (e.g., lantana (*Lantana camara)*, Christmas berry, koa haole, Guinea grass (*Megathyrsus maximus*)) plants are used (Mitchell 2013). In many areas Nēnē feed on cultivated grasses. The species selected for this project not only provide suitable seabird habitat, but also provide suitable Nēnē forage.

Given that non-native vegetation was not part of the original habitat of Nihoku, it is expected that the restoration activities will ultimately be beneficial for soils in returning soil chemistry to a previous state. Moreover, if the restored native coastal habitat encourages more nesting seabirds, this would increase the amount of guano input into soils. It is anticipated that this would be a beneficial effect that could assist in restoring nutrient cycles and other ecosystem processes. Overall, effects from habitat restoration are anticipated to be positive in the long term, despite short term disturbance (Mitchell 2013).

7.2 Methods

Timeline and sequence

The timing of restoration activities was selected for logistical reasons in year one in order to ensure that predators had been removed, but prior to the seabird translocation. As a result of these constraints, clearing and planting occurred in October 2015, which also corresponded to the onset of the rainy season. Restoration work in subsequent years occurred in late May or early June in order to avoid the Nēnē breeding season. During each restoration phase, invasive species were cleared in a 1-2 week period, and native plants that had been grown offsite were immediately outplanted after clearing had been completed to stabilize the soil. Thus the restoration activities were done in a relatively short period of time each year.

Clearing methods

Clearing methods varied somewhat by year as past experiences informed future events, so they are presented chronologically. In summary, a combination of mechanical removal with heavy machinery and herbicide was used to clear up to one acre of invasive weeds each year.

In October 2015, Christmas berry, the dominant invasive, was mechanically removed with a five ton excavator with a mulching head, followed by application of 17% Garlon 4 Ultra specialty herbicide (manufactured by Dow Agro Sciences) in biodiesel on the stump, leaving the root system in place to maintain soil integrity while the plants died. This method has been used in multiple restoration projects in Hawaiʻi with proven success. Non-native grasses were mowed to keep their stature short, and any other woody vegetation was cut and treated with Garlon. Large scale clearing took approximately two weeks and was done in the center of the fenced area to clear the slopes most suitable for seabird habitat first.

In June 2016, protocols were changed somewhat and a hydroax was used to remove Christmasberry by chipping it down to the stump and leaving the root system in place to maintain soil integrity while the plants died. Garlon was applied the next day and minimal Christmasberry sprouting has been observed to date. This method took three days and was approximately 60% less expensive than using an excavator and required less labor.

For the June 2017 clearing, the same protocols as 2016 were used to clear just under 0.4 ha (one acre) of invasive weeds. While these methods have been mostly successfully at keeping Christmasberry out of the area, we will likely experiment with pre-treating the Christmasberry with Garlon prior to cutting and chipping in 2018.

During all clearing events, best management practices were incorporated to minimize the potential for erosion and included: avoiding the use of heavy equipment in the steeper and more erosion-prone portion of the project area, phasing restoration over multiple years to reduce exposed ground areas, avoiding earthwork in inclement weather, using vegetative buffers for erosion control and soil stabilization, and re-vegetating of bare areas with native coastal plants in the days immediately after clearing had taken place.

Irrigation system

To ensure that a high proportion of native plants that were out-planted survived, a drip-irrigation and water catchment system was installed in November 2015. An existing 2,500 gallon catchment tank was re-located from Crater Hill to inside the fenced area and a corrugated roof was built on top to catch rain. An extensive drip irrigation network was placed throughout the planting area and set on a timer to water at dawn and dusk. The system was designed so that the hoses and pipes could be re-located as new restoration areas are planned within the fence each year. The irrigation lines were moved each year in the weeks after out planting to provide water support for the new seedlings.

Native plant propagation and out planting

The native plant species chosen to plant (Table 3) were selected based on historical and current distribution of suitable native coastal plants, recommendations by Bruegmann and Castillo (1999) in the KPNWR restoration plan, as well as species that provide seabird habitat and Nēnē forage. The native plants are low-in-stature, thus making burrow excavation easier for the birds, while simultaneously being low-maintenance and providing forage for Nēnē.

Plants grown for this project were produced from seed to maximize genetic diversity of each species. Propagules were collected in areas near the site or from similar and appropriate habitat on Kauaʻi. Seeds were sown on fine black cinder then transplanted into a custom blend potting mix of coco coir and perlite. Once seeds were established in their pots they were set up in a full sun part of the nursery to harden them. Irrigation was reduced to acclimate the plants to drier conditions to enhance survivorship after they were out planted.

Table 3: Plant species and quantity planted at Nihoku from 2015-2017.

Species scientific name	Hawaiian name	# planted
Artemisia australis	Ahinahina	94
Bidens sandwicensis	Koʻokoʻolau	43
Boerhavia repens	Anena	45
Canavalia kauaiensis	Kauaʻi Jackbean	94
Capparis sandwicense	Maia Pilo	50
Carex wahuensis	ʻUki ʻUki	1,444
Chenopodium oahuense	Alaweo	541
Colobrina asiatica	Anapanapa	375
Cyperus javanicus	Ahuawa	1145
Dodonaea sp.		124
Dodonaea viscosa	Aʻalii	200
Erythrina sandwicensis	Wiliwili	5
Euphorbia celastroides	ʻAkoko	239
Fimbristylis cymosa	Mauʻu ʻAkiʻaki	1038
Gossypium tomentosum	Mao	56
Heteropogon contortus	Pili	1198
Jacquemontia ovalifolia	Pau O Hiʻiaka	504
Kadua littoralis	Manono	55
Lipochaeta connata	Nehe	219
Lipochaeta succulenta	Nehe	93
Lycium sandwicense	Ohelo Kai	380
Myoporum sandwicense	Naio	231
Nototrichium sandwicense	Kului	161
Osteomeles anthyllidifolia	ʻŪlei	738
Pandanus tectorius	Hala	13
Peperomia blanda	Alaʻala	56

Plumago zeylanica	Hilieʻe	588
Pritchardia hillebrandii	Loʻulu Lelo	2
Psydrax odorata	Alaheʻe	146
Rumex albescens	Huʻahuʻakō	56
Scaevola taccada	Naupaka	450
Sida fallax	Ilima	244
Sporobolus virginicus	ʻAki ʻAki	5,566
Vigna marina	Nanea	273
Vitex rotundifolia	Pohinahina	1124

Propagation of seedlings was done by the National Tropical Botanical Garden (NTBG) at their Lawai nursery and followed sterile growing procedures to reduce the chance of introducing pests to the area. All biological content brought onto the site for restoration followed the Hawaiʻi rare plant restoration group (HRPRG) sanitation guidelines to prevent the spread of, or introduction of invasive species and pathogens (guidelines can be downloaded here: http://hrprg2.webnode.com/recommended-guidelines/phytosanitation-standards-and-guidelines/).

Plants were grown in a covered area isolated from weed species by at least a six foot buffer, including root systems. Growing media was sterile and from the approved growing media list provided by HRPRG, and tools used were disinfected regularly before use. Plants grown were inspected prior to being brought on-site. All species were subjected to a hardiness test before large scale out-planting.

Plants were out-planted in the 2015 restoration area in late October 2015 and again in June 2016 and 2017. During the 2016 and 2017 restoration activities, out planting was done by volunteer groups of 25 individuals over two days with guidance on placement from NTBG staff. Shrubs were spaced throughout the artificial burrow area to help produce shade and reduce the temperature in the burrows. Grasses and sedges were predominantly planted in the flatter areas below the artificial burrows to provide forage for Nēnē.

During the 2017 out planting, tropical fire ants were noticed on the ground at the NTBG nursery near plants that were being loaded to take to the Nihoku the same day. At the time that the ants were noticed, more than half of the 7,800 plants had already been placed at Nihoku. A rapid fire ant survey using spam deployed on wax paper for one hour was done in the trucks containing all the plants, and over 25% of the area at Nihoku; no fire ants were detected on either the newly arrived plants, nor the plants already on-site. As a precaution, all arriving plants and the newly cleared area were treated with granular Amdro. Follow up surveys were done site wide at Nihoku as well as at the NTBG nursery in September 2017. While no fire ants were detected at Nihoku, there were in fact fire ants detected at the nursery. As a result, biosecurity protocols at both the nursery and Nihoku were revisited in order to prevent the spread of invertebrate pests to the area.

7.3 Outcomes

Almost 1.2 ha (3 ac) were cleared of invasive weeds and close to 18,000 native plants representing 36 species were out-planted in the first three years of restoration at Nihoku. While there was some mortality associated with trampling around the artificial burrows and Nēnē browsing, it is estimated that greater than 50% of outplanted seedlings survived and are covering the majority of the cleared area. Active weeding is done quarterly to ensure that restoration areas remain native-dominated. In future years, more shrubs will be planted for better cover, and an attempt will be made to determine a better age for outplanting key Nēnē forage species so that the Nēnē don't inadvertently kill the plants (from over-browsing) before they establish. In total, approximately 40% of the project area was restored from 2015-2017, and restoration efforts will continue in future years.

Figure 20: Nihoku restoration areas, the yellow line indicates the area cleared and revegetated in 2015, the red line indicates the area cleared in 2016. On the right are native plants from the 2015 planting cohort.

Figure 21: 2017 Nihoku restoration areas before planting (left) and during (right).

8 SEABIRD TRANSLOCATION PLAN

This section covers the seabird translocation plan that was implemented, but does not include final results from the translocation itself.

8.1 Introduction

Translocation as a tool for seabird conservation

Birds in the Order Procellariiformes exhibit strong natal philopatry and high nest-site fidelity. These behavioral traits, along with a protracted nesting period and ground nesting habit, result in great vulnerability to predation by introduced mammals and exploitation by humans at the breeding colonies (Croxall et al. 2012). This vulnerability has led to the extirpation of many island populations of Shearwaters and Petrels around the world and made the consequences of stochastic events such as hurricanes, volcanic eruptions, epizootics, or fires at the remaining safe breeding sites much more significant (Jones et al. 2008, Croxall et al. 2012).

Translocation of birds to restore former breeding colonies or to create new colonies that are protected is a strategy that is being used as a conservation measure with increasing frequency, particularly in situations where social attraction techniques are not adequate on their own. Guidelines for the appropriateness, planning, implementation, and monitoring of such actions have been written for the Agreement on the Conservation of Albatrosses and Petrels (ACAP; Gummer et al. 2013) and similar guidelines were adopted by the IUCN Species Survival Commission in 2012 (http://www.issg.org/pdf/publications/Translocation-Guidelines-2012.pdf). The key methods employed to establish new colonies of burrow-nesting seabirds are acoustic attraction, provision of artificial burrows, and chick translocation.

Translocations involving hand-rearing of burrow-nesting Procellariiforms have been undertaken around the world, but particularly in New Zealand since the early 1990s (Bell et al. 2005, Miskelly and Taylor 2004, Carlisle et al. 2012). Eight species from four different genera had been translocated by 2008 (Miskelly et al. 2009) and several more species have been translocated since (Gummer 2013; T. Ward-Smith, pers. comm.) with each success building upon the last. Furthermore, translocations have been undertaken successfully for highly endangered Procellariiforms including Bermuda Cahow (*P. cahow)* and New Zealand Taiko (*P. magenta)*, where the world population has numbered fewer than 100 breeding pairs. Techniques have been developed for most of these species to a level where health issues are minimal and all transferred chicks fledge at body sizes similar to or exceeding those of naturally-raised chicks (Gummer 2013). Transferring Procellariiform chicks to a new colony site is just the beginning of a long process of colony establishment that depends on survival of the translocated birds, their recruitment to the new colony site, and the social attraction of other pre-breeding individuals that will accelerate the growth of the colony into a viable population.

While successes in early years of translocation development varied (Miskelly et al. 2009), recent years have seen successes as measured by recruitment of translocated chicks to the translocation site for a variety of species. In the Chatham Island Taiko, 60% of the 21 chicks transferred over 2007 and 2008 have been recaptured as adults (M. Bell, Chatham Islands Taiko

Trust, pers. comm. 2013), and up to 20% of translocated cohorts of Chatham and Pycroft's Petrels (*P. axillaris* and *P. pycrofti)*, translocated in the early-mid 2000s have returned to their respective release sites as adults (H. Gummer and G. Taylor, pers. comm.). Miskelly and Gummer (2013) reported that 20 of 240 Fairy Prions *(Pachyptila turtur*) transferred by 2004 were recovered at the release site despite 25 translocated birds being attracted back to the abundant source population. In addition, there has been some recruitment of non-translocated birds at new colony sites of multiple species through the use of acoustic attraction (H. Gummer, pers. comm.). Miskelly and Taylor (2004) reported that 17% of Common Diving-Petrels (*Pelecanoides urinatrix*) transferred in the late 1990s were recovered at the release site. That project has also shown the highest recruitment rate of non-translocated birds compared to all other New Zealand species, with 80 immigrants recorded within 11 years of the first chick translocation (Miskelly et al. 2009). During the three years of HAPE translocations to Nihoku, 98% (49/50) of chicks survived to successfully fledge. In summary, the numerous well-documented efforts that have been undertaken over the last 20 years have laid a solid foundation for translocating new species on islands outside of New Zealand.

In Hawaiʻi, recovery plans for the threatened Newell's Shearwater and the endangered Hawaiian Petrel specifically list translocation as a highly ranked recovery action. The purpose of this section is to outline the steps required to initiate translocation for Hawaiʻi's two endemic seabirds. The results of the translocation itself will be presented a separate manuscript in the future.

Newell's Shearwater biology

Newell's Shearwater is a threatened subspecies that is endemic to the Hawaiian Islands. It is closely related to the Townsend's Shearwater (*Puffinus a. auricularis*) found in the eastern Pacific. Newell's Shearwaters are a medium-sized Shearwater (391 g; King and Gould 1967). They are black above with a white belly, throat, and underwings, and a distinctive white patch on the flanks. Newell's Shearwaters are highly pelagic and forage over deep waters. They range throughout the tropical Eastern Pacific up to 3,000 miles from the Hawaiian Islands south to the Equatorial Countercurrent (Ainley et al. 1997). Their primary prey are ommastrephid flying squid (99%) and flying fish (*Exocoetus* sp.; Ainley et al. 2014), which are taken by pursuit plunging up to 30m, and scavenging, often in association with tuna and other sub-surface predators.

The population of NESH was estimated to be 84,000 birds including 14,600 breeding pairs in the 1990's (Cooper and Day 1994, Spear et al. 1995, Ainley et al. 1997), and approximately 27,011 birds in 2006 (Joyce 2013). Newell's Shearwaters are now primarily restricted to Kauaʻi which supports ~ 90% of the breeding population; very small numbers may also breed on Lehua Islet, Oʻahu, Molokaʻi, Maui and Hawaiʻi Island (Ainley et al. 1997, Reynolds and Ritchotte 1997, VanderWerf et al. 2007). The population on Kauaʻi is thought to have declined by over 94% from 1993-2013, based on radar and fallout data, indicating that the current population is likely much lower (Raine et al. 2017), although accurate numbers and trend indicators are difficult to obtain due to the inaccessibility of breeding colonies. Identified causes of the decline include urbanization including collisions with utility lines and light attraction and subsequent disorientation/fallout, depredation by introduced predators, habitat loss and degradation, , and natural catastrophes (Ainley et al. 1997, Raine et al. 2017).

Newell's Shearwaters are at least loosely colonial and nest in burrows, crevices, or under vegetation. On Kauaʻi, they breed in two habitat types: 1) high elevation, steep, wet montane forest dominated by native vegetation with an uluhe fern understory) and 2) steep dry cliffs (predominantly along the Na Pali coast). Newell's Shearwaters breed from April to November (Ainley et al. 1997) and are K-selected species, are characterized by a long lifespan (at least 20 years), low fecundity (one chick per year), and delayed recruitment (3-7 years; Ainley et al. 1997, Simons and Hodges 1998). Pairs are monogamous and show a high degree of nest site fidelity. A single egg is laid in a burrow or on the ground and parental care is equally distributed between the sexes. The incubation period is 62 days and the chick-rearing period is 92 days. Chicks are fed a regurgitated mixture of squid and fish; of samples regurgitated at burrow entrances during one study (N=9), squid were the only prey item (Ainley et al. 1997). Fledglings collected dead under power lines from 1993-94 (N=19) and 2001-2009 (N=79) had their stomach contents analyzed to determine their diet (Ainley et al. 2014). Their diets were 94-99% squid, dominated by ommastrephid (flying) squid (37-57%) and cranchiid squid (7-16%). Fish comprised 0.1-4% of their diet, with the primary species being *Exocoetus* flyingfish. Chicks are fed every 1-3 days by their parents (Ainley et al. 1997; Ainley et al. 2014). Imprinting on the natal site appears to occur after the date of the chick's first emergence from the burrow, which, based on remote camera data is 14.9±1.8 days before fledging (n=9 days, range 7-25) (Kauaʻi Endangered Seabird Recovery Project (KESRP; unpubl. data). Average fledging mass of chicks is 430g and fledging occurs at ~86 days of age based on data gathered from 2003-2005 and in 2014 at Kīlauea Point National Wildlife Refuge (KPNWR; USFWS unpubl. data; PRC unpubl. data).

Threats to NESH are many and varied. Predation from non-native animals on the breeding colonies, including feral cats, feral pigs, rats and Barn Owls have all been documented (Ainley et al. 1997, Raine et al. 2017). Additionally, the presence of small Indian mongooses on Kauaʻi was confirmed recently when two animals were captured in May and June 2012 near the airport and the harbor (Honolulu Star-Advertiser 2012; Duffy et al. 2015). Numerous other sightings have been reported but have not been confirmed. If this predator were to become established on Kauaʻi it would likely be catastrophic for NESH.

Light attraction and collision with artificial structures (fallout) is also a large source of mortality for NESH. On Kauaʻi, more than 32,000 Newell's Shearwaters have been collected by SOS as victims of fallout from 1979-2008, with the numbers decreasing over time in tandem with an overall population collapse (Day et al. 2003, Raine et al. 2017). Fledglings are the main victim of light attraction and fall-out because it is thought that they use the moon and stars to guide them to the ocean on their maiden flight out to sea and thus become confused when other sources of light are present. Collision with artificial structures, predominantly power lines, is also a major source of mortality for adults, particularly breeding adults moving to and from montane breeding colonies to the sea (KESRP unpub data; Raine et al. 2017). Habitat loss is often compounded with predation from non-native animals as reduction in dense native canopy cover can provide access for predators into breeding colonies (Raine et al. 2017). Finally, NESH are likely susceptible to marine-based threats, but little is known about threats in the marine environment. Newell's Shearwaters depend on tuna to force prey within reach (Harrison 1990). Tuna schools in eastern tropical Pacific are the target of widespread and efficient commercial fisheries, and several tuna species now are considered to be in jeopardy (IUCN 1996). Determining possible food web impacts remains key, as will the impacts of a warming ocean on their prey distribution (USFWS 2013). Ingestion of plastic may also be a problem for this species, although ingestion rates were much lower than for Wedge-tailed Shearwater (Kain et al. 2016).

As a result of the suite of threats that have been observed to impact the species over many decades, NESH were listed as threatened under the U.S. Endangered Species Act (ESA) in 1975 (USFWS 1983). Conservation actions were begun in the 1970's, most notably the Save our Shearwaters (SOS) program, in which the public was encouraged to bring fallout birds to rehabilitation facilities. Predator control, habitat restoration and other conservation measures have followed in recent years (KESRP unpub data).

At KPNWR, a single record of NESH nesting at the site exists from 1945 (Pyle and Pyle 2017). In response to declines in the montane colonies, in 1978 and 1980, 65 and 25 NESH eggs were translocated to Kīlauea Point and Mokuʻaeʻae Island (just offshore of KPNWR), respectively, and cross-fostered by Wedge-tailed Shearwater (WTSH) pairs in an attempt to establish a NESH colony at a protected site. Seventy-nine percent of these eggs hatched and 94% of the chicks fledged (Byrd et al. 1984) and several pairs of NESH now breed at KPNWR today. These NESH pairs are assumed to be descendants of the original cross-fostered chicks as well as new recruits attracted to the acoustic attraction system (USFWS pers. comm.). The current breeding habitat at Kīlauea Point is open-canopy hala forest with a naupaka understory. Between one and three pairs were known to breed at the Refuge since the 1970's, but with the advent of a social attraction project at the site in 2007 the number of known nest sites increased to 22, 11 of which were active in 2013, 11 in 2014, nine in 2015 and nine in 2016 (KESRP unpubl. data). Three chicks hatched and banded on Refuge in 1997, 2006, and 2009 have returned as breeders or prospectors. All nests are located on the parcel of the Refuge that contains the lighthouse and administration buildings and is open to the public.

In recent years, WTSH appear to have actively displaced several NESH pairs at KPNWR – with two NESH pairs being displaced in 2013, seven in 2015 and eight in 2016 by incubating WTSH (KESRP unpub data). It is thought that the two species may compete for nesting space at lower elevations. These observations could partly explain the paucity of NESH in the coastal fossil record relative to WTSH (Olson and James 1982a and 1982b). Being the larger and earlier arriving species, WTSH often are the winner in these confrontations, and it is unknown whether they simply displace NESH adults from preferred burrows, or if they inflict harm on the adults themselves. Recent survey work by KESRP using burrow cameras at KPNWR has recorded aggressive encounters between WTSH and NESH, with WTSH charging NESH with wings outstretched and chasing them away from previously occupied burrows (KESRP unpub data).

Additional conservation actions are needed to help counter the ongoing decline in Newell's Shearwater numbers. Managing threats on their remote colonies is critical, but is also logistically challenging and costly. Creating (and augmenting) colonies at sites that are easier to access and have been secured against predators is however an additional method for ensuring the on-going persistence of this specie and is a high priority conservation action.

Hawaiian Petrel biology

The Hawaiian Petrel, one of the larger *Pterodroma* Petrels (434g; Simons 1985), was formerly treated as a subspecies of *P. phaeopygia* and was formerly known as the Dark-rumped Petrel (USFWS 1983) until it was reclassified as a full species due to differences in morphology, vocalization and genetics from birds in the Galapagos Islands (Tomkins and Milne 1991). Hawaiian Petrels previously had a widespread prehistoric distribution throughout the Hawaiian Islands, including low elevation coastal plains on Oʻahu, Kauaʻi (such as Makauwahi Caves), and other islands (Olson and James 1982). Today, the breeding population is estimated to be 6,500-8,300 pairs with a total population of ~19,000 (Spear et al. 1995, Ainley et al. 1997), and approximately 52,186 in 2006 (Joyce 2013). On Kauaʻi, the population has declined by 78% between 1993 and 2013 (Raine et al 2017) and is thought to be as a result of collisions with power lines, fallout associated with light attraction, predation on the breeding colonies by introduced mammals and Barn Owls, , and habitat loss (Raine et al 2017). On Kauaʻi only a few HAPE are collected each year during the fallout period, but it is not clear whether this is because they are less susceptible than NESH to light attraction or because their main breeding areas are less affected by light pollution. Hawaiian Petrels were listed as endangered under the ESA in 1967.

Hawaiian Petrels are known to breed on Hawaiʻi Island, Maui, Lanaʻi and Kauaʻi, with a small, unconfirmed colony on Molokaʻi (Ainley et al. 1997, Penniman et al. 2008). Known breeding habitat varies. On Haleakalā (Maui) and Mauna Loa (Hawaiʻi) Hawaiian Petrels breed in open, rocky subalpine habitat at high-elevation. On Lanaʻi, Kauaʻi, West Maui and Molokaʻi, they breed in wet montane forest with dense uluhe fern, similar to NESH (VanZant et al 2014). While at sea during the breeding season, Hawaiian Petrels undertake long-distance, clockwise looping foraging trips over large areas of the North Pacific, sometimes traveling up to 10,000 miles in a single trip (Adams and Flora 2010; KESRP unpublished data). When not breeding, they range widely over the central tropical Pacific (Simons and Hodges1998). Their diet has been extensively studied and is composed primarily of squid (50-75% of volume), followed by a suite of reef fishes that possess pelagic juvenile stages (Simons 1985). Based on the prey species and their behavior, they are assumed to be primarily nocturnal foragers.

Hawaiian Petrels are also a K-selected species and are characterized by a long lifespan (up to 35 years), low fecundity (one chick per year), and delayed recruitment (5-6 years; Simons and Hodges 1998). Most pairs show a high degree of nest site fidelity and often remain with the same mate for consecutive years. A single egg is laid in a burrow or on the ground and parental care is equally distributed between the sexes. The incubation and chick-rearing periods are 55 and 110 days, respectively with some variation in phenology between islands. Chicks are fed an average of 35.6 g of regurgitated squid, fish and stomach oil during the last three weeks of the rearing period, and larger amounts, 55.4-63.3 g, earlier in the rearing period (Simons 1985). Imprinting on the natal site appears to occur after the chick's first emergence from the burrow, which on Kauaʻi is 15.8±0.94 days before fledging (n=22, min=7, max=29; KESRP unpub data). Average fledging mass of chicks on Maui is 434g, which is similar to adult weights (424g; Simons 1985), though it should be noted that birds from Kauaʻi appear to be smaller in build than those from Maui (Judge et al. 2014). Average wing cord at fledging for birds nesting on Kauaʻi is 281.36 ± 10.90 mm (Judge et al. 2014).

Managing threats on their remote colonies is critical, but is also logistically challenging and costly. Creating (and augmenting) colonies in easier to access, safe locations is therefore an important complementary conservation strategy. Although HAPE have not been documented to breed at KPNWR, the restored portions of the Refuge (such as that within the fenced area) provides habitat that is comparable to what would have been found in their historic coastal range. The presence of HAPE in the fossil layer indicates that this species was formerly numerous on the coastal plains of Oʻahu and Kauaʻi.

This plan has been developed specifically for translocating NESH and HAPE from nesting sites on Kauaʻi where predation is occurring, to the predator exclusion fence area at Nihoku within KPNWR. This plan outlines the information necessary to conduct the translocation.

8.2 TRANSLOCATION SITE PREPARATION

Translocation site selection and preparation considerations

Conservation practitioners are obligated to ensure that a proposed translocation site is safe and under a land management regime that ideally provides protection in perpetuity with a management plan in place. Based on guidelines set out by the population and conservation status working group of the Agreement on the Conservation of Albatrosses and Petrels (ACAP; Gummer et al. 2013), a translocation site should fulfill the following criteria:

- A suitable geographic site with respect to topography, access to the ocean, strength and direction of prevailing winds, ease of take-off and landing, nesting substrate, reasonable distance to adequate foraging grounds, and sufficient elevation to preclude periodic inundation from storm waves;
- Free of predators and invasive species harmful to Procellariiforms, or fenced (prior to translocations) to exclude such species, or a regular control program to remove those detrimental species;
- Surveyed prior to the translocation for the presence of any endemic species (flora or fauna) that could potentially be disturbed by the project, or that could influence the success of colony establishment;
- Adjacent to a cliff, elevated above the surroundings, or relatively free of man-made or natural obstructions that could inhibit fledging and arrivals and departures of adults;
- Relatively accessible to biologists, to facilitate delivery of supplies and monitoring;
- Designated for long-term conservation use;

- A site for which other conflicting uses (e.g. local fishing, aircraft operations, city lights, busy roads, and antennae, etc.) have been considered and conflict avoidance measures are feasible;
- Be free of, or have minimal, known human threats to the species (such as light attraction or power lines) within its immediate vicinity.

Site preparation

Ideally, the site selected for the translocation should already have substrate and vegetation structure preferred by the species to be translocated. If there are plants that create collision hazards or block the wind and cause over-heating by preventing convective cooling, they should be removed. For burrow-nesting species, artificial burrows need to be installed to accommodate translocated chicks and to provide suitable nesting sites for prospecting adults.

It is also important to have a sound system (solar-powered) continuously playing species-specific calls from existing breeding colonies. While decoys are not commonly used for burrowing seabirds, they may help attract birds to the area (this is currently being trialed by First Wind for both NESH and HAPE at two predator exclusion fenced enclosures in Maui at Makmakaʻole). The decoys and sound system serve two purposes: (1) They provide visual and auditory stimuli to the developing chicks, which may allow them to re-locate the site when they attain breeding age; and (2) The calls and visual cues may attract others of the species to the site. Juveniles that were not reared at the site and have not yet bred may choose to breed at the site, thereby helping to increase the population.

Nihoku site selection

The site selected for Hawaiʻi's first translocation of listed seabirds is the Nihoku section of Kīlauea Point National Wildlife Refuge. This site fulfills all of the criteria described above. Kīlauea Point National Wildlife Refuge was set aside in perpetuity in 1985 by the federal government "to preserve and enhance seabird nesting colonies and was expanded in 1988 to include Crater Hill and Mōkōlea Point" (USFWS). Located at the northern tip of the island of Kauaʻi, the 203 acre Kīlauea Point National Wildlife Refuge is home to thousands of nesting seabirds, including Laysan Albatrosses (*Phoebastria immutabilis)*, Red-footed Boobies (*Sula sula)*, Red-tailed Tropicbirds (*Phaethon rubricauda*) and White-tailed Tropicbirds (*P. lepturus*), Wedge-tailed Shearwaters (*Puffinus pacificus)* and several pairs of Newell's Shearwater as well as numerous pairs of Nēnē or Hawaiian Goose (*Branta sandvicensis*). In addition, many migratory and resident seabird species frequent the area when not nesting. The area is managed for native birds by the U.S. Fish and Wildlife Service through predator control, habitat management (both weeding and outplanting), and fencing.

The Nihoku project site consists of approximately 6.2 acres between Crater Hill and Mōkōlea Point, just south of Makapili Rock and approximately 1.5 kilometers northeast of Kīlauea town. Nihoku faces the ocean, on sloping land (approximately 23° slope) above steep sea cliffs. The elevation ranges from approximately 140 to 250 feet above mean sea level; well above all scenarios of projected sea level rise as a result of climate change. The area has a natural 'bowl' shape and the orientation facing towards the ocean and prevailing northeast winds make it an ideal location for birds to be directed straight out to sea. The natural cliffs and ridgelines made it ideal to tuck a fence behind to reduce the possibility of birds colliding with the fence, to facilitate take-off for flight and to reduce light pollution from private residences adjacent to the Refuge. It was also a relatively simple location on which to build a fence and conduct a translocation due to easy access from a nearby road.

Nihoku site preparation

Site preparation at Nihoku consisted of three phases: fence construction, predator removal, and habitat restoration. Those activities have been discussed in detailed earlier in the document, but are summarized below for ease of accessibility.

Fence construction was done by a contractor specializing in fence construction took three months. Immediately after fence construction, all remaining invasive mammalian pests were removed. Based on monitoring results and regulatory restrictions, a combination of diphacinone in bait boxes spaced 25m apart and multiple-catch mouse traps was used to eradicate rodents, and live traps were used to remove cats. These methods were successfully used to eradicate all mammalian pests from a pest-exclusion fenced area at Ka‘ena Point in 2011 (Young et al. 2013). Following fence construction, just under three acres (45%) of the project area was cleared of invasive alien plants and suitable native species were out-planted.

Standard artificial burrow designs used in New Zealand for similar Procellariformes species are 5-sided wooden boxes (four sides plus a lid) with open bottoms and corrugated plastic PVC tubes for burrow entrances. A similar design is used for NESH, but with a lighter weight plastic that has been used for the tropical nesting Bermuda Cahow and Audubon’s Shearwater in the Carribean.

Figure 22: Nihoku artificial burrows prior to being installed.

The nest boxes that were used were manufactured by the Bermuda Audubon Society with 0.3 cm thick High Density Polyethylene (HDPE) and fabricated in a size for accommodating all burrow/cavity nesting seabirds in the weight range 250 – 600g (see attached specifications). HDPE is chemically inert and very durable and the thickness is strong enough to resist warping or physical damage from trampling, tree-fall and rock-fall in most circumstances, especially when buried in soil substrate. The burrows (pictured above) are square boxes measuring 50 x 50 cm and are 38 cm high. They have hinged lids for easy access and a modular tunnel component that can be cut to any length and with 225˚ angled sleeves to allow the tunnel to make turns (to keep out light). The opening of the tunnel is 15cm in diameter.

Burrows were installed in 2015 and were dug into the ground so that just the lid was exposed. The lids were painted white and had holes drilled in the side to allow for airflow. Finally, sandbags were placed on burrow lids to reduce thermal fluctuations. Temperatures were monitored for several weeks, and by painting, drilling and covering the lids, we reduced the average temperature by 2**°**C, and most importantly reduced the upper end of the range from 30**°**C to 25**°**C. Temperature monitoring continued during the initial HAPE translocation and all chicks appeared to thermoregulate normally within this temperature range. The burrow floor, which is open to the ground, was covered with a layer of tumbled pea gravel topped with wood shavings to prevent flooding and mud accumulation.

Interactions and impacts with other species

Based on the species currently present in the project area, with the exception of Barn Owls and Wedge-tailed Shearwater, no negative interactions are anticipated between NESH or HAPE and any other animal or plant in the fenced area site. The successful establishment of these seabirds in the site would likely increase soil fertility, with benefits for a wide range of species. However, the presence of Barn Owls at the site is a concern since they cannot be excluded from the area and are known seabird predators. During the translocation period and ideally throughout the life of this project, Barn Owl control would be implemented to prevent any of the fledglings from being taken by Owls. Control during the recruitment period is done on an as-needed basis.

While there are no WTSH nesting currently in the project area, they do nest nearby (closest colony is <250m and one pair is immediately outside the fenced area) and it is possible that once the habitat has been prepared and artificial burrows are installed, that the area may become attractive for this species and that they may move into the project area. Wedge-tailed Shearwaters have been known to displace NESH from breeding burrows (USFWS &KESRP unpub data) and potentially inflict harm on NESH adults. To prevent WTSH from displacing returning NESH and HAPE chicks, artificial burrow entrances are blocked until the beginning of the NESH arrival period (early April) since WTSH tend to arrive on the breeding colonies earlier than NESH. It is hoped that this action will discourage WTSH from nesting in the artificial burrows to reduce potential interactions between the two species at the site. In the event that all artificial burrows are occupied, additional burrows will be installed on an as-needed basis if birds will not use the naturally occurring features at the site. Removal or relocation of WTSH may need to be considered if WTSH pose a problem.

8.3 SOURCE SITE SELECTION

Surveys to locate potential donor colonies

From 2012-2017, KESRP undertook a series of surveys at known NESH and HAPE breeding sites to locate potential donor colonies for this project. These surveys were initially undertaken at colonies which were considered to have the highest threat of extirpation – due to fallout, power line collision, predation, and habitat loss as well as the colony at KPNWR due to its proximity to the Nihoku site.

Surveys at these sites were conducted using a standardized auditory survey protocol developed by KESRP, with 2 hour evening surveys beginning at sunset and 1.5 hour morning surveys beginning 2 hours before sunrise. Surveys were conducted during the peak breeding season when birds are most vocal – June to beginning of September. Surveys were accompanied by burrow searches in areas where the highest levels of ground calling activity were identified.

In 2012, a total of 167 surveys were conducted at five colonies – KPNWR, Makaleha, Kahili/Kalaheo, North Fork Wailua and Koluahonu. The highest call rate was found at the North Fork Wailua Colony (an average of 217 calls/ hour), and the lowest at the Koluahonu Colony (56 calls/ hour). Three new burrows were located in the Kahili region, one at the Kalaheo colony and 11 burrows were found to be active in KPNWR. Additionally, locations of high calling rates or potential ground calling were identified at all sites.

In 2013, the focus shifted somewhat. As well as undertaking surveys at five low elevation sites with high risk of colony extirpation, three higher-elevation sites were also included. These areas had known colonies of both NESH and HAPE, and had higher levels of activity when compared with the low elevation sites and had active colony management. These sites were included in the surveys due to the low success of locating nest sites in the low elevation sites (and that there were very few birds left at these sites). As with 2012, KPNWR was also included in the surveys. A total of 165 surveys were therefore conducted at nine colonies in 2013 - KPNWR, Makaleha, Kahili/Kalaheo, North Fork Wailua, Koluahonu, Sleeping Giant, Upper Limahuli Preserve and Hono o Na Pali North Bog. The highest call rate was found at one of the higher elevation sites, Upper Limahuli Preserve (an average of 363 calls/ hour), and the lowest at the Koluahonu Colony (79 calls/ hour) and KPNWR (77 calls/hour).

In 2014, due to the very low number of burrows located in colonies with a high risk of extirpation, surveys focused on higher elevation sites with large concentrations of birds as well as KPNWR. A small number of surveys were also undertaken at North Fork Wailua, Kahili and Kapalaoa. At the end of this period, all sites surveyed over the last three years were considered for feasibility for a translocation project. These were ranked on the following criteria: (i) presence of breeding colony, (ii) known burrows present, (iii) threat level, (iv) on-site predator control and (v) accessibility. For Hawaiian Petrel, the four sites that scored the highest ranking were (in descending order): Pihea (HNP), Upper Limahuli Preserve, North Bog (HNP) and Hanakapia'i. For Newell's Shearwater, the four sites that scored the highest ranking were (in descending order): Kīlauea Point NWR, Upper Limahuli Preserve, Pohakea (HNP) and Kahili.

Potential effects of removal

The proposed removal of up to 90 NESH and HAPE chicks from up to four colonies (with a minimum of 158 active nests) over a five year period (10-20 per year depending on the year) will likely have minimal impacts on the local, or species level populations. The largest colonies (Upper Limahuli Preserve and North Bog) had a minimum of 82 NESH and 79 HAPE known burrows and in 2015 produced a minimum of 60 chicks. If one considers the number of known NESH and HAPE burrows in these two colonies and assumes all are active in the first year of translocation then the proposed total take of 10 nestlings based on 2015 numbers is a small proportion (12.2-12.7%) of total production at those sites. However, Upper Limahuli Preserve is a very important colony and under its current management regime (presently via funding from the Kaua'i Island Utility Cooperative {KIUC}) has a very high reproductive success rate. Therefore, chicks would not only come from this site - under the proposed removal regime for the translocation project only 3-4 nestlings would be removed from each site – in which case 4 nestlings would represent 4.9-5.1% of total known burrows at any one site. It should also be noted that new burrows are found each year (i.e., in 2015 a further 18 NESH burrows were located at Upper Limahuli Preserve alone) and therefore there are almost certainly many more birds breeding within the selected donor areas. Thus, the proportion of chicks removed is likely much lower.

Considering the small number of chicks taken out of any colony in a given year, coupled with the use of different burrows in different years (i.e., chicks would not be removed from the same burrow in consecutive years if at all possible), it is unlikely that this will have a measurable impact on the local, or species level population of NESH or HAPE since the vast majority of the translocation chicks are expected to fledge. In other species, much higher proportions of nestlings are removed from the colonies for conservation purposes. In the critically endangered Cahow and in the Taiko, 100% of the chicks produced for the species are removed each year to start a new colony (since both species are restricted to a single colony; Carlisle et al. 2012).

It is important to consider predation levels at current colonies. In areas where no predator control is occurring, predation levels of breeding seabirds and their chicks can be extremely high. For example, several historical NESH colonies on Kauaʻi (such as Makaleha and Koluahonu) have been depleted to the point of near-extirpation in the last decade. Makaleha in particular is an interesting case as this site has only been monitored using helicopter-deployed song meters and auditory surveys from a ridge on the other side of the valley, so there has been no human ingress to this site at all and no management. In the span of ten years this site has gone from having call rates as high as Upper Limahuli to having call rates that are sporadic at best (Raine *pers comm*). Ainley et al. (1995) reported 23 NESH killed by cats in the Kahaleo colony in 1993 alone and Jones (2000) found that New Zealand Shearwater colonies would disappear within the next 20-40 years on the mainland of New Zealand without significant management actions to eliminate predation by introduced mammals. Chicks that would be removed and hand-reared at a translocation site would likely have higher survival than chicks from sites without predator control. Furthermore, monitoring of predation levels of nesting endangered seabirds in areas on Kauaʻi where predator control is currently on-going has revealed that while significantly reduced, predation of chicks - in particular by feral cats, pigs and Black Rats - is still an issue (KESRP unpub data). For example, at North Bog in Hono o Na Pali NARS, 25% of all monitored NESH chicks were killed by rats in 2013 and 9.2% in 2014 (KESRP unpub data). Cats continue to predate upon both species at all sites every year, with cat predation events recorded in all three Hono o Na Pali sites in 2014 and 2015. Cat depredation has been particular bad on Newell's Shearwater at Pohakea, for example. Therefore, survival to fledgling of birds in these colonies is already reduced. With the above being the case, the removal of three or four chicks in a given year from several different colonies, regardless of whether predator control is occurring, is unlikely to cause any issues with the overall recruitment of source colonies since a portion of the translocation chicks would not have survived to fledge in the source colonies regardless.

Another concern is the potential desertion of breeding pairs from burrows where chicks have been removed for translocation purposes. This has not been a serious issue in previous projects. In a number of other translocation studies (Miskelley et al. 2009); adults return the following year despite the removal of their chick prior to fledging. There is also some suggestion in related species that breeding pairs whose chicks die (or in the case of translocation are removed) may have a higher survival rate as they are able to spend more time foraging for self-maintenance compared to pairs with an active chick (VanderWerf & Young 2011). In NESH burrows currently monitored on Kauaʻi, breeding pairs return in subsequent years after their chicks have been depredated and successfully fledge young in the following year (KESRP unpub data), and initial observations indicate parents whose chicks have been removed for translocation also return

The translocation to Nihoku is also likely to be neutral from a genetic perspective since very few seabirds (or land birds) have distinct genetic structure of populations on the same island. It is likely that many NESH populations on Kauaʻi were at one point continuous and are only now discrete as a result of habitat fragmentation and population declines (Olson and James 1982a and 1982b). Potential impacts of human visitation at source colonies that could be considered are damage to nesting habitat by repeat visits, disturbance resulting in temporary or permanent burrow desertion by adults (although this has never been recorded in areas currently monitored on Kauaʻi at a frequency of up to eight visits per year), and the creation of trails to burrows that could be used by introduced predators. These potential impacts are minimized by:

- Following existing trails whenever possible, taking care to avoid creating new trails;
- Concentrating only on areas where predator control is on-going, so that animals that may be attracted to the area will have reduced impacts;
- Repairing all burrows damaged accidentally by trampling;
- Minimizing the number of visits to each burrow and using burrow cameras to help assess viability of any given burrow for use as a source bird for translocation; and
- Using a team of two trained people on nestling collection trips to minimize disturbance levels.

8.4 COLLECTION AND REMOVAL OF DONOR CHICKS

Age at translocation

Age of the chick at translocation is an important variable that needs to be optimized to allow chicks the longest time possible with their natural parents for species imprinting, transfer of gut flora, and expert parental care without losing the opportunity for the chicks to imprint on the translocation site and increase the probability that they will eventually recruit to the new site. In addition to thermoregulatory and nutritional benefits, it is possible that rearing by parent birds for the first month minimizes the chance that the chicks will imprint on humans, and allows transfer of parents' stomach oil (and possibly unknown species-specific micronutrients or antibodies) to the very young chicks.

Burrow-nesting seabird chicks are thought to gain cues from their surroundings during the emergence period shortly before fledging, and then use that information to imprint on their natal colony (location imprinting). Chicks that have never ventured outside natal burrows can be successfully translocated to a new colony location. Success is optimized if chicks spend the greater proportion of the rearing period with parents before being moved.

For NESH, age of first emergence is 14.9±1.8 days before fledging (n=9, min=7, max 25) (KESRP unpub data). Based on morphometric measurements collected (USFWS unpub data, PRC unpub data), this would appear to be when at a minimum mass of 400g and wing cord of 189mm, or a ratio of 2.1 mass/wing cord. This occurs in mid-late September based on on-going data collection at active burrows using Reconyx cameras. Trips are made to source colonies in mid to late September, and cameras are checked to see whether the chicks have emerged. Those that have not emerged, and appear to be in good health are selected.

For HAPE, age of first emergence is 15.8±0.94 days before fledging (n=22, min=7, max=29) (KESRP unpub data). This occurs in late October to beginning of November based on on-going data collection at active burrows using Reconyx cameras. Trips are made to source colonies in mid-October, and cameras are checked to see whether the chicks have emerged. Those that have not emerged, and appear to be in good health are selected.

Number of chicks in each translocation cohort, and number of cohorts
Factors important in choosing a cohort size for a chick translocation are genetics, rate of growth of the new colony, size of the source colony and the practical limitations of logistical capability and labor to care for the translocated chicks. Since these translocations involve only chicks of long-lived birds, it is unlikely that taking the proposed number of the chicks from the parent colony will affect the viability of that source population as it might have if one moved adult animals.

In New Zealand, for established translocation programs for burrowing species, a maximum of 100 chicks a year is considered appropriate to transfer for project totals of up to 500 birds over a five year period. The recommended number of chicks to transfer to a new site in the first year of a project is generally 50 chicks if the team is new to seabird translocations, and/or there are anticipated logistical issues to resolve at the release site (Gummer 2013). If the species has never been translocated before, a trial transfer of a small number of chicks (e.g., ≤10) may be appropriate to test artificial burrow design and hand-rearing methods. The conservative approach of up to 10 chicks in year one is what was used with both species.

Translocation projects ideally should span several years to increase the genetic heterogeneity of the translocated population, to accelerate the development of a natural population age structure at the new site, to increase the size of the translocation group within the staff capabilities for chick rearing, and to “spread the risk” associated with environmental stochasticity. Transferring a minimum of 200 chicks of burrow-nesting species over a 3−4 year period has now been tested on several projects in New Zealand. With increased confidence in techniques, it is now considered advantageous to move more than this to increase the pool of birds returning to the establishing colony site and the encounter rate of conspecifics, which is thought to be important in encouraging adults to settle there (Gummer 2013). Supplementary translocations in later years may also need to be considered to achieve this goal. It should be noted that even with the expertise to manage large numbers of birds on the translocation site, it is unlikely that enough suitable donor burrows will be located for such large cohorts. Thus, more transfers of smaller cohorts may be necessary to achieve the same objective.

For the first year of NESH and HAPE translocations, 10 chicks will be removed and transferred to Nihoku following recommendations developed in New Zealand for new translocation projects. If fledging exceeded 70%, then up to 20 birds would be moved in years 2-5 for a total of 50-90 birds. Considering the rarity of these species, available nesting burrows in multiple colonies will be one of the main limiting factors in any given year. If fledging is below 50% in any given year, the project will be re-evaluated before proceeding. If fledging criteria are not met at any stage, numbers will not be increased until those numbers are met. The number of birds may also depend on whether additional suitable donor burrows can be located. The goal of this project is to transfer a minimum of 50 and up to 90 chicks over a five year period.

Pre-capture monitoring

All potential source colonies are being monitored on a regular basis by the KESRP. Ten monitoring trips are carried out to these sites each year and are undertaken once a month. Trips are made, based on the following schedule: (i) pre-arrival, to deploy cameras and song meters (late February), (ii) arrival on breeding colonies (March), (iii) arrival of NESH (April), (iv) incubation period (1 or 2 trips in June-July), (v) early chick-rearing period (1 or 2 trips in August-September), (vi) fledging or late chick-rearing period for NESH in October and (vii) fledging or late chick-rearing period for HAPE in November. This schedule is flexible depending on logistical considerations and project priorities.

During each visit, identified burrows are inspected to assess breeding status as per the standardized protocols outlined below. At all times, care is taken to minimize damage to surrounding vegetation and burrow structure through careful approach to and from the burrow site, with staff paying particular attention to vegetation and potential areas where the ground could collapse.

At each check, notes are made on any signs of activity within or around the nest. This includes (i) the presence of adult, egg or chick, (ii) scent, signs of digging or trampling, and/or (iii) presence of feathers, guano or egg shell. A note is also be made as to whether or not it was possible to see to the back of the burrow (e.g. was the burrow fully inspected, or was there a possibility that something was missed). Any signs of predation (such as a dead adult or chick in front of burrow or inside burrow), or the presence of scat/droppings/prints that indicate a predator has been in the vicinity of the nest, are also recorded.

A sub-set of burrows (30) are also monitored by cameras (Reconyx Hyperfire PC900). These cameras are mounted on poles located 3-10ft away from the burrow entrance and set on a rapid fire setting (motion sensor activated, with a trigger speed of 1.5sec). 8GB SD cards are used to record photographs, and these (along with the rechargeable batteries) are switched out on each visit to ensure continuous coverage over the season. If a burrow fails during the season or the chick successfully fledges, then the camera is moved to a new active burrow until the breeding season is over.

At the end of the season, a final status is assigned to each nest using the following categories:

- *Active, breeding confirmed* – breeding was confirmed as having been initiated during the season through the presence of an egg or chick. For this category, the outcome is noted as either:
    - *Success* – Nest successfully fledged a chick. As the site is remote and not visited regularly enough to actually see the chick fledge, a successful fledging is

considered in the following scenario – A chick was confirmed in burrow up until typical fledging month (November/early December) and on the following check (i) the presence of small amounts of down outside the nest site indicate that the chick was active outside the burrow and subsequently fledged and/or (ii) there are no signs of predation or predator presence. Burrows with cameras provide information on exact fledging date and time. Translocated chicks would be considered as being in this category for the purposes of colony monitoring.
    - *Failure* – Nest did not fledge a chick. The failure stage (egg or chick) and cause of failure (predation of chick or egg, abandonment, predation of breeding adult, etc.) is recorded where known. Burrows with cameras can provide information on predation events and predator visitations pertinent to nest failure.
    - *Outcome Unknown*- Breeding was confirmed at the site, however no subsequent visits were made, no visits were made late enough in the season to confirm fledging, or signs were inconclusive. Only a very small number of burrows fit into this category as every effort is made to assess the final status of all burrows.
- *Active, unknown* – the presence of an adult bird, or signs of an adult bird (guano, feathers, trampling, etc.) indicate that a bird was present during the breeding season but it was not possible to confirm whether breeding occurred and failed or breeding was never initiated. Either way no chick fledged. Situations like this arise in instances where (i) it was not possible to examine the back of the nesting chamber due to the structure of the burrow, (ii) an adult bird was confirmed in the burrow during the incubation period, but it was not possible to determine if it was incubating an egg, or (iii) the burrow is discovered late in the breeding season and, as it was not therefore monitored during the egg-laying period, it is not clear if breeding had been initiated (even if eggshell fragments are recorded, as they could have been from previous seasons).
- *Active, not productive* - the presence of an adult bird, or signs of an adult bird (guano, feathers, trampling, etc.) indicate that a bird was present during the breeding season but burrow inspections reveal that no breeding took place (i.e. no egg was ever laid).
- *Prospecting* – bird(s) recorded visiting nest, but signs are indicative that these are prospecting and not breeding birds. Examples would be new excavations within a previously inactive burrow, a single visit during the breeding season to a previously inactive burrow, a visit to a burrow where both adults had been confirmed killed the year before, or the preliminary excavation of a burrow-like structure combined with the confirmed presence of a seabird.
- *Inactive* – no sign that the burrow has been visited in that breeding season.

Additional visits are made to the sites each year to actively search for new burrows. Burrows that are found during these trips are added to the overall monitored group of burrows at the site, as detailed above.

Selection of individual chicks to be moved
Chicks selected for translocation will be chicks that appear healthy and in good condition and are in burrows where they can be safely (and easily) removed. Chicks fledging in optimum condition have an improved chance of surviving and returning as adults. Ideally, chicks will

meet species-specific criteria on the day of transfer (Gummer 2013), and thus, a combination of wing cord and mass measurements will be used to select chicks if enough burrows exist to allow for selection criteria to be implemented (see below for target measurements). Setting a transfer wing-length range ensures that only chicks of appropriate age are taken. Setting minimum transfer weights for different wing-length groupings ensures chicks can recover weight lost during transfer and while adapting to the hand-rearing diet, and still fledge in optimum condition. In addition, it is vital that chicks have not emerged at the source colony yet for even a single night to avoid imprinting on their natal site. Since all potential donor burrows will be monitored with cameras, it will be known if the chick has emerged.

Due to the limited number of burrows available from which to select chicks, every effort will be made to select chicks that meet the age (size) criteria set above. In the event that there are not enough burrows to choose from, we will select burrows where the chicks a) are reachable by hand from the burrow entrance and b) have not yet emerged from their burrow based on nest camera information/data.

Over multiple transfer years, efforts will be made to maximize representation of different parents from different parts of the source colony. This prevents the same adult pair from being targeted for chick removal in subsequent years, potentially disrupting their pair bond by forcing them to 'fail' multiple times in their breeding attempts. Therefore, burrows that were used for a translocation in the previous breeding season will not be used in a second consecutive season but may be used every other season if necessary.

Chick capture and transport

Minimizing the risks of overheating and injury in the carrying containers, and stress from unfamiliar stimuli, are major considerations for the chick capture and transport phase. The transfer box design used for most burrow-nesting Petrel transfers in New Zealand is based on a standard pet (cat) box (Gummer 2013) and will be used for both NESH and HAPE. There must be enough space and ventilation to avoid overheating issues, and to minimize wing and tail feather damage of the more advanced chicks. Boxes will also be heat-reflective, dark inside to reduce chick stress levels, and have padded flooring (yoga mats) that provides grip and absorption of waste or regurgitant. Since only a small number of chicks will be taken, one box per chick will be used. Chicks will be removed by hand from the burrow, and placed into transfer boxes. Boxes will then be loaded into the cabin of the helicopter and secured to a seat for flight using rope. Once they have arrived at the Princeville airport (~15 minute flight from the natal colonies), they will be transferred into a vehicle and likewise secured into a passenger seat for transfer to the translocation site (~30 minute drive). It is expected that birds will be in their transfer boxes for 4 hours maximum and every effort will be made to ensure that transfer time is as short as possible. Upon arrival at Nihoku, each chick will be banded to help with individual identification and future recaptures as adults on the site.

Post-collection donor colony monitoring

Each year, all of the colonies being used as source colonies will be monitored to assess potential effects of the translocation of chicks on the future breeding efforts of donor burrows. For birds that are transferred from areas already under management and monitoring regimes, all burrows will already be monitored ten times spanning the breeding season to assess whether the burrow is active, breeding has been initiated, whether a chick has hatched and whether a chick has fledged (see pre-collection monitoring for details). As all burrows are given a unique identification tag, the progress of each burrow in any given season is known. It will therefore be possible to assess whether burrows used as donor burrows in the previous season show any change in productivity in the following year. If a negative effect is noted, then the translocation protocols will be re-assessed. All burrows used as donor burrows in 2015 were active in 2016 and the same was true in 2017 for donor burrows in 2016 (KESRP, unpub data).

8.5 CHICK CARE AT THE NEW COLONY SITE

Burrow blockage procedures

In order to ensure that newly translocated chicks do not wander out of the burrow prematurely, entrances will be blocked on both ends of the entrance tube. The interior entrance to the burrow chamber from the tube will be blocked with a square panel of metal mesh screening to allow airflow, and the exterior entrance will likewise be blocked with a similar mesh screen to allow for airflow. Because of the curve in the burrow tunnel, light penetration into the burrow chamber is minimal. A double-sided blocking procedure is done to ensure that chicks do not get trapped in the tunnel if they attempt to leave the burrow by blocking both entrances to the tunnel. The exterior entrance block is to prevent newly emerged chicks from adjacent burrows wandering into the burrow opening and similarly are unable to turn around when they reach the interior chamber mesh screening.

Burrow blocks will be removed on an individual basis depending on chick developmental stage and proximity to fledging. Blocks will not be removed until NESH chicks have reached the minimum wing cord length required to fledge.

- Wing length: ≥220 mm
- Weight: ≥350 g
- Down cover: Not exceeding 60% (looking down on chick from above)
- Wing growth rate: Slowed from up to 9 mm/day, down to <5 mm/day

For HAPE, Criteria are as follows based on 90 day old chicks (~1 month prior to fledging) from Simons 1985 and Judge et al 2014:

- Wing length: ≥170 mm
- Weight: ≥500 g
- Down cover: Not exceeding 60% (looking down on chick from above)
- Wing growth rate: Slowed from up to 9 mm/day, down to <5 mm/day

Down cover should not be relied on as a sole guide to gate removal as it can be prematurely lost on the transfer day, or through handling, especially in wet weather. Down coverage is recorded by visually estimating the percentage of down left when looking down on the chick from above. Down-cover percentage is used as a cue to preventing premature blockade removal; chicks with ≥60% estimated cover are not allowed to emerge, especially if they are lighter in weight, as they are considered to be too far from fledging and may be compromised without further meals if they disappeared.

Blocking the entrances of burrows will also be undertaken prior to the NESH breeding season to minimize the possibility that WTSH will take over the nesting sites. Burrows will be blocked once all birds have fledged and will remain blocked until the start of the HAPE breeding season at the beginning of March and will have cameras deployed on them to determine if WTSH are actively investigating the burrows.

Diet and feeding procedures
All meals will be prepared off-site either at a private residence with access to electricity and water, or at the Refuge headquarters. All meals will be prepared at room temperature and transported to the translocation site in a cooler each day and all clean-up will be done at the same location to maintain hygienic standards (outlined below).

Recipe
Previous projects in New Zealand have used 1 (106 g) tin Brunswick™ sardines (89%) in soy oil (10%) (including oil contents), one-third Mazuri™ Vita-zu bird tablet (vitamin supplement) coupled with 50 ml cold (boiled > 3 min) water. This diet is stable at room temperature (prior to preparation) and is easy to obtain and bring into the field. It also was the clear winner in a feeding trial conducted by Miskelley et al. (2009) of translocation projects in New Zealand.

Preparing food:
Mazuri tablets (or portions of tablets) will be crushed to as fine a powder as possible. The tablets do not dissolve, so crushing to a fine dust allows the vitamins to be equally distributed in the mixture. If making four tins of fish (700ml total volume), 200 ml cold (boiled > 3 mins) water (or unflavored pedialyte) will be placed in a blender with two tins of fish and blended until runny (at least 30 sec). A third tin of chopped fish (or equal mass of fresh fish) will then be added and blended until runny. Vitamin powder will then be added through hole in lid while blender running at low speed. The fourth tin of chopped fish will be added and blended until smooth. The mixture will be kept cold until immediately before feeding.

Food will be warmed immediately (<10 min) before feeding to prevent bacterial build up. Temperature will be tested on with a thermometer and will not exceed 33°C (cold mix e.g. <30°C may be rejected by chick; hot mix e.g. >35°C may damage chick's internal tissues). Food temperature will be monitored regularly (aiming for ~ 33ºC) and stirred with a spoon before drawing up food (the thick part of the mix can settle).

Retrieving chicks from burrows:
The methods outlined below are for two-person teams (a feeder permanently at the feeding station located by the artificial burrows and a handler/runner collecting, holding and returning

chicks). Prior to starting feeding for the day, complete rounds of all occupied burrows to check on welfare of all birds will occur. Each burrow will be visited in numerical order (to ensure all are checked), and the overall welfare of the chick will be checked in addition to signs of regurgitation in burrow, or abnormal excrement, and for any signs of digging in blockaded burrows. Any missing chicks will be searched for, including in un-occupied artificial burrows, in the event that they wander into an adjacent burrow.

Chicks will be processed in the following order:

1. Extract from burrow
2. Weigh (to obtain pre-feed or base weight)
3. Check band
4. Measure wing length (right wing) if wing measuring day
5. Any other handling (e.g. physical examination, down coverage estimates)
6. Feed (recording amount delivered in ml; no post-feed weight required)
7. Return to burrow

When birds are removed, they will be placed in a carrying box. Carrier boxes will have a clothes pin that is attached from each burrow with the burrow number on it to ensure birds are placed back in their proper burrow. After feeding, the chick is returned to its burrow and the clothes pin is clipped to its burrow lid. This helps to prevent confusion during feeding and eliminates the carrier's need to remember which burrow their chick came from.

<u>Feeding chicks:</u>

All feeding will be done on a clean surface (folding table) located in the shade above the colony. On rainy days, a pop-up tent will be erected to provide cover. The handler will hold the chick firmly on a surface (with towel) with a loose hand grip—the chick must not be tightly gripped or it will not feed properly and the crop area in particular needs to be unrestricted. The feeder will hold open the bill (mainly grasping the upper bill), stretching the head and neck out (at approx. 30–40º angle from the horizontal). With other hand holding the syringe, the feeder inserts the crop tube to the back and side of the throat (to keep airway clear). Food delivery will be at least 30 seconds for a 40 g batch, with at least one rest approximately half way (c. 20 ml) through syringe load to check for any signs of meal rejection. Food delivery will stop at the pre-determined amount or earlier if there are signs of food coming back up throat. The bill will be immediately released as the crop tube is withdrawn, so that if there is any regurgitation the food can be projected clear of the plumage and risk of aspirating food is reduced.

Figure 22: Demonstration of proper feeding technique, and apparatus from the 2015 HAPE translocation to KPNWR.

After feeding, the chick will be cleaned with a soft tissue so that there is no food on the bill or plumage. Soiling of the plumage with foreign materials can disrupt water-proofing and insulation. Particular attention will be paid to the base of the bill where food can build up and form a crust if not cleaned away. The amount of food actually taken by a chick will be recorded. Any details regarding food delivery e.g. regurgitation, overflow, appears full, difficult feeder requiring plenty of breaks, resists food, good feed etc. will be recorded to help with the planning of subsequent meal sizes.

Chicks will be fed amounts according to their weights on the day after transfer. Chicks will be fed up to 15% of their body weight on any given day, and food consumption will be adjusted to mimic the natural growth curve in wild chicks of each species.

<u>Sterilization procedures</u>
Maintaining sterile conditions for husbandry tasks will be crucial to preventing infections in the transferred chicks. Food storage, preparation and cleaning will all occur at the Refuge where there will be access to electricity, a sink and refrigerator; meals will be carried in a cooler to Nihoku immediately prior to feeding. Microshields™ chlorhexidine (5%) will be used for all disinfecting tasks. All feeding and food prep instruments and tools will be disinfected using chlorhexidine and rinsed using boiled water prior to commencing feeding. Each individual bird will have its own sterile syringe and stomach tube each day to avoid cross-contamination between feedings. All work surfaces will be wiped down with kitchen towels and disinfectant spray (or leftover sterilizing solution), or with antibacterial surface wipes both before and after feedings. Any weigh boxes that have been used will be washed, rinsed, and set out to dry.

Chick health and morphometric monitoring

As well as the physical health check made prior to transfer, a full physical examination will be given when chicks arrive at the release site, and at any point thereafter where there is unexpected and/or unusual chick behavior or posture. The Short-tailed Albatross (*Phoebastria albatrus*) translocation team collected blood samples to compare 9 different blood chemistry parameters with the same ones in naturally reared chicks (Deguchi *et al.* 2012a, b) and to characterize the effects of transmitter attachment and handling on hand-reared chicks. These measures provided insight into health status and body condition of the artificially reared birds. The results found better nutritional status in hand-reared birds than those raised by wild parents but evidence of possible muscle damage or capture myopathy in birds handled for transmitter attachment. At a minimum, NESH chicks to be transferred will have baseline blood panels and disease screening conducted on the day of transfer, and then again close to fledging.

All efforts will be made to minimize regurgitation, and to handle chicks in such a way that regurgitant can be projected away from the body. Regurgitation can have serious consequences, including soiling of plumage spoiling water-proofing and insulation; possible asphyxiation; and, aspiration of food particles leading to respiratory illness. Burrows will be carefully inspected for signs of regurgitation, especially while chicks adjust to a new diet and feeding regime, and to ensure chicks are passing normal feces and urates.

Other serious health issues that staff will be aware of include: ventriculitis/proventriculitis injury (caused by gut stasis or food contamination); aspiration of food (caused by regurgitation or poor feeding technique); and dehydration and heat stress. Appropriate first-aid treatment will be available if chicks injure themselves during the emergence period (see veterinary care and necropsy section).

Aside from basic health checks, one of the most important measurements that will be used in decision-making will be chick mass. Chicks will be weighed by placing them in a tared weigh box onto a table-top scale. The box will be cleaned between each chick measurement. Weight will be recorded in grams. Wing measurements may be made every 2-3 days to assist with planning meals and gate removal. Wing measurements will be taken at the following intervals and done less frequently than weight since a higher chance of injury is associated with wing measurements:

- Day of transfer in natal colony
- Soon after transfer on translocation site
- When wings are predicted to be around 210 mm in length for NESH/ 270mm for HAPE (based on a daily growth rate of up to 8 mm/day);
- 3–5 days later to determine the wing growth rate once chicks had reached or exceeded 220 or 275mm (to help schedule blockade removal).
- On alternate days, once blockades are removed to record departure wing lengths. Wing measurements can stop being measured once three measurements read the same (i.e. wing has stopped growing).

- Younger chicks can also be measured at opportunistic intervals, to monitor progress,

To measure wing length, birds will be kept in bags (to keep calm), and the right wing will be removed to measure—straightened and flattened to record maximum wing chord. Whenever possible, this measurement will be done by the same person to reduce inter-observer bias. If the potential exists for two observers to take measurements, they will be calibrated against each other to apply any needed corrections to the data.

Fledging criteria

Chicks of New Zealand species are not allowed to exit burrows before they have reached the minimum known first emergence wing-length for the species (emerging species), or are just short of the minimum known fledging wing-length (species fledging on the first night outside the burrow). Burrow blockade removal strategies have been developed to ensure that chicks do not leave the burrow prematurely and still have a good chance of fledging, even if at the lower end of the target fledging weight range for the species. Secondary criteria are species-specific and include weight, wing-growth rates and down coverage (Gummer 2013).

These strategies are necessary since it can be difficult to find chicks that have left their burrows. Lighter chicks that need to be fed daily are at the greatest risk if they can no longer receive meals, and some species are more prone to disappearing than others (e.g. Fluttering Shearwaters, *Puffinus gavia*; Gummer and Adams 2010). For both species, fledging criteria will be a combination of the measurements described below, a slowing of wing growth and reduced down.

Veterinary needs and necropsy protocols

Veterinary care will be provided locally by Dr. Joanne Woltman, DVM at Kauaʻi Veterinary Clinic and all efforts will be made to stabilize chicks in the field so that they can remain at the translocation site. In the event that a chick cannot be stabilized in the field, it will be sent to the Save our Shearwaters facility at the Kauaʻi Humane Society in Lihue for intensive care. Any chicks that expire during the process will be sent to Dr. Work at USGS for a full necropsy to determine the cause of death.

8.6 TRANSLOCATION ASSESSMENT

Measuring success

Establishment or restoration of colonies of Procellariiforms is a long-term commitment and markers of success will be incremental. Milestones that can be quantified include:

- Proportion of chicks that survive capture and transfer to new site
- Proportion of chicks that fledge from the colony
- Body condition of fledged chicks
- Proportion of translocated chicks that return to the new colony from which they fledged
- Number of prospecting birds fledged from other colonies that visit the translocation site.
- Number of those birds fledged from other sites that recruit to the new colony.

- Reproductive performance (hatching success, fledging success) of birds breeding in the new colony.
- Natural recruitment of chicks raised completely in the new colony
- Annual population growth within new colony

Most projects involving transfers of burrow nesting species in New Zealand have employed most, if not all, of the methods described above to monitor their success.

Monitoring success at Nihoku

Success at Nihoku will be monitored at various stages of the project. Items 1-3 from Table 4 below will be measured in each year during the translocation itself. Items 4-8 will be measured over time- starting 3-5 years after the first translocation cohort fledges (i.e. after sufficient time has passed for birds to return to the site as adults). If birds are identified during these checks, the burrows will be regularly monitored through the duration of the breeding season. It is hoped that by year five, there will be at least one active breeding pair at the site.

	Success Metric	**Nihoku Target**
1	% chicks that survive capture and transfer to new site	90% year one; 100% afterwards
2	Body condition of fledged chicks	Wing and mass measurements ≥ wild chicks
3	% chicks that fledge from the new colony	70% year one; 80% afterwards
4	% translocated chicks that return to the new colony (by age four)	NESH: ≥ 15% (estimated return rate of existing KPNWR colony)- 40% (cumulative survival rate from 0-4 years from Greisemer and Holmes 2011) HAPE: ≥ 27% (rate of survival in unprotected colonies)
5	# birds fledged from other colonies that visit the translocation site	>0 (i.e. any visitors considered successful)
6	# birds fledged from other sites that recruit to the new colony	>0 (i.e. any new recruits considered successful)
7	Reproductive performance of birds breeding in the new colony.	Reproductive success ≥ wild colonies with predation (NESH: 0.2-0.5; Greisemer and Holmes 2011); HAPE (39-61%; Simons 1985)
8	Natural recruitment of chicks raised completely in the new colony	NESH: ≥15% (estimated return rate of existing KPNWR colony) - 33% (rate of survival in unprotected colonies from Greisemer and Holmes 2011) and by year 6

		HAPE: ≥ 27% (rate of survival in unprotected colonies) and by year 10

Table 4: Metrics of success and targets used to determine translocation outcomes.

9 CONCLUSIONS

9.1 Summary

As with any multi-phase project that invokes contemporary techniques at the forefront of island conservation, there are lessons learned along the way that can serve future projects. The goals of this report were not only to document the process that this project went through, but also to provide some constructive suggestions for future projects so that others can learn from both what was and was not done correctly. As time passes, future publications will be put out on the ultimate results of the translocation as well as the results of ecosystem recovery.

9.2 Acknowledgements

This project and manuscript are part of a large collaboration that spans beyond the agencies mentioned. Many individuals were consulted for advice and input along the way. For botanical and invertebrate advice, we thank: David Burney, Lida Burney, Natalia Tangalin, Emory Griffin-Noyes, Kawika Winter, Kim Starr, Forest Starr, Sheldon Plentovich and Keren Gunderson. For assistance with translocation training and predator exclusion fence technical advice we thank Helen Gummer, John McLennan, Lindsay Wilson, and Darren Peters. For reviewing documents related to this project, and for feedback on techniques we thank the seabird hui, particularly Fern Duvall, Jay Penniman, Megan Laut, Darcy Hu and Cathleen Bailey. For their on the ground assistance at KPNWR, we thank: Shannon Smith, Chadd Smith, Warren Madeira, Rob Petersen, Jennifer Waipa, Padraic Gallagher, Carolyn Rushforth, Kristina Macaulay, Jimmy Macaulay, and Jillian Cosgrove. We would also like to thank Chris Mottley, Kyle Pias and the entire predator control team in Hono o Na Pali NAR and Kawika Winter, Chiemi Nagle, Merlin Edmonds and the entire predator control team in Upper Limahuli Preserve. We would also like to thank the Kauaʻi Island Utility Co-operative (KIUC) for the funding that they provide – through a Habitat Conservation Plan – to provide predator control and seabird monitoring at several of the sites used for translocation. Lastly, we would like to thank all of the endangered seabird technicians within the Kauaʻi Endangered Seabird Recovery Project for all of their hard work in montane colonies. Mahalo.

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